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Complexity and Chaos - State-of-the-Art; List of Works, Experts, Organizations, Projects, Journals, Conferences and Tools

M. Couture
DRDC Valcartier

Defence R&D Canada – Valcartier
Technical Note
DRDC Valcartier TN 2006-450
September 2007

Canada

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This work is part of project 15bp01 – Defensive Software Design.

Abstract

This report contains a number of 471 references to scientific works, organizations, scientific journals, conferences, experts and tools, plus 713 additional potential Internet addresses. References of this list are related to Complexity Theory, chaos and complex systems.

Résumé

Ce rapport contient une liste de 471 références à des ouvrages scientifiques, des organisations, des revues scientifiques, des conférences, des experts et des outils, plus 713 adresses Internet additionnelles. Les références de cette liste sont reliées à la théorie de la complexité, au chaos et aux systèmes complexes.

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Acknowledgements

The author would like to thank Mister Robert Charpentier from DRDC Valcartier for his support during all this work.

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1 Introduction

This document aims at assembling a number of references to relevant books, papers, experts and organizations as well as tools that are directly or indirectly related to Complexity Theory and complex systems. Many abstracts and additional comments are added to each reference for completeness.

1.1 Contexts and Scopes

This document is the first of a set of five DRDC Valcartier reports dedicated to the study of complexity theory, chaos and complex systems (Couture, 2006a, 2006b, 2006c, and one to be published in 2007). It is part of an overarching project being carried on at DRDC Valcartier, Project 15bp01 – Defensive Software Design. It focuses mainly on the presentation of concepts from this theory. There are only a few references to the architecting and engineering aspects of complexity. These aspects will be covered in another document.

1.2 The Used Methodology

Figure 1 depicts the general methodology used for this study. It is characterized by a main iterative and incremental loop (steps 1 and 2), which includes a number of sequential and parallel activities (steps 3, 4 and 5). This loop permits on-the-fly adjustment and optimization.

The five main activities or steps are:

1. **Search literature, projects, groups, etc**: Internet searches were made using Google and other search engines. A number of specialized databases were also searched (Dialog Database Catalog, 2005). These databases are listed in Annex C of Couture (2006a).
2. **Select potentially useful documents**: Documents were selected based on their potential applicability to the military context.
3. **Study selected documents**: Approximately 30–40% of the selected documents were read and studied in greater detail.
4. **Investigate in greater depth for the military context**: This involved finding elements that offer potential solutions in the military context.
5. **Update documents**: The content of each document was updated on the fly at each iteration.

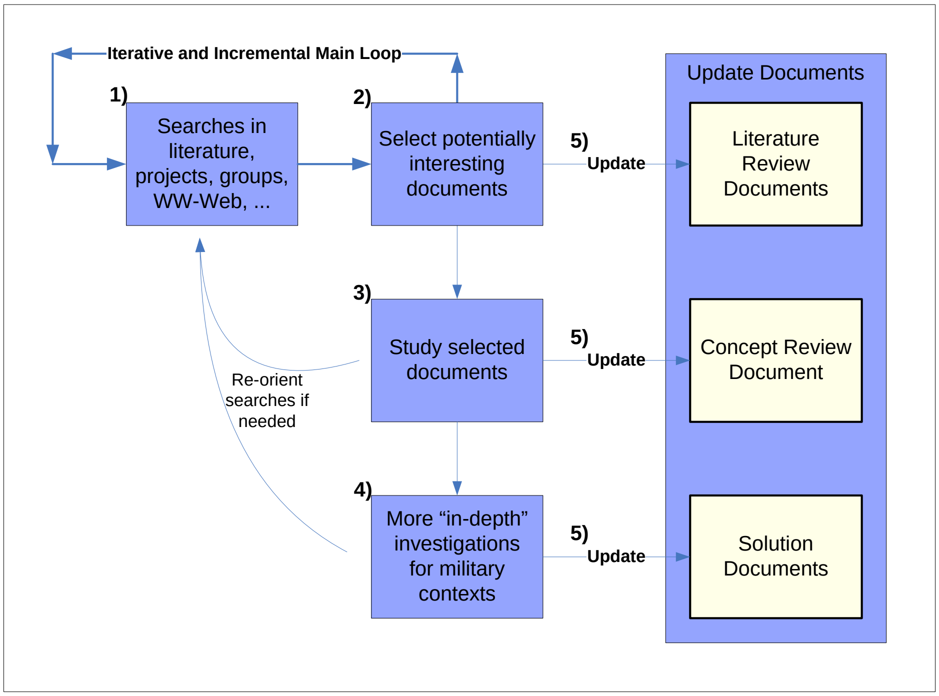

Figure 1 The Methodology Used in this Work.

The reports generated by this study are listed in Table 1. The first four reports will be published by the end of phase one of the study (by March 2007). The last will be published by the end of phase two (late 2007).

Table 1 List of Documents Issued from this Work.

Title	Description
Complexity and chaos – State-of-the-art; List of works, experts, organizations, projects, journals, conferences and tools. (This document).	This Technical Note provides 471 references to scientific studies, organizations, scientific journals, conferences, experts and tools, plus 713 additional Internet addresses that are related to complexity theory, chaos and complex systems. Abstracts are included where available.
Complexity and chaos – State-of-the-art; Formulations and measures of complexity. (Couture, 2006b).	Different formulations and measures of system complexity are provided in this Technical Note. They were drawn from the scientific literature on complexity theory, chaos and complex systems.
Complexity and chaos – State-of-the-art; Glossary. (Couture, 2006c).	This Technical Note defines 335 key words related to complexity theory, chaos and complex systems. The definitions were extracted from the scientific literature.
Complexity and chaos – State-of-the-art; Overview of theoretical concepts. (Couture, 2007).	This Technical Memorandum presents an overview of theoretical concepts pertaining to complexity theory.
Complexity and chaos – State-of-the-art; The Engineering of complex adaptive systems. (To be published in 2007).	Descriptions of the current approaches, methodologies and tools used to address problems related to the architecting, engineering and improvement of complex systems is included in this Technical Report.

1.3 How to use this Document

This report is a starting point reference for the search of information on Complexity Theory, chaos and complex systems. Considering the quantity of information included in this document, two ways of searching are proposed:

- **To get a general survey on a specific subject**: The reader may simply use the Table of Content for locating specific subjects.
- **To find specific information on a specific subject**: The reader must use its word processor's search engine to find all appearances of selected key words within this

document. S/he will also find appropriate key words and addresses that can be re-used in further searches over the Internet for instance.

2 General Theory of System and Systems Thinking

2.1 General Theory of System

<u>Book</u>: Théorie générale des systèmes 2ième édition (Bertalanffy, 1993)

Author(s):

Ludwig Von Bertalanffy

Comments from DRDC reviewer:

This is a re-edition of the classic book "General System Theory" from Ludwig Von Bertalanffy, first published in 1968 (Publisher: Georges Braziller, Inc. New York). It is a fundamental source of information on concepts related to the general Theory of Systems.

2.2 Systems Thinking

<u>Scientific document</u>: A Systems Thinking Approach to Selecting Systems Methodologies for Defence High-Level Systems (Cook and Allison, 1998)

Author(s):

S. C. Cook and J. S. Allison

ACTE, University of South Australia, The Levels Compus, Mawson Lakes, SA, 5090.

From the document:

This paper endeavours to identify systems methodology that could prove useful in the creation and operation of military systems -of-systems. The paper opens with a review of basic systems thinking and proposes a military systems hierarchy that is useful in characterising military systems on the basis of their behaviour and the relevant disciplines with which each can be brought to bear. We then examine the system thinking framework called Total Systems Intervention described by Flood and Jackson (1991) and discuss how this can help select a systems methodology for the range of defence systems identified in the hierarchy. The paper concludes by suggesting a how TSI might be tailored to defence needs, in particular, high-level systems.

Comments from DRDC reviewer:

The authors identify some problems with traditional Systems Engineering when applied to complex military projects. They then identify a list of seven principles of Total System Intervention. Propositions are then made for further researches in the domain.

Scientific document: Engineering Systems and Systems Thinking (Frank, 2000)

Author(s):

Frank Moti

Technion – Israel Institute of Technology, Haifa 32000, Israel.

From the document:

This article deals with the question what distinguishes "engineering systems thinking" from " systems thinking"? Based on research findings, Senge's systems thinking laws were "adapted" to the "engineering systems thinking" - some were substantially modified, some replaced, and in some only the phrasing was changed. In addition, new laws were added. Thirty "engineering systems thinking" laws are suggested. The first stage in the development of an engineering curriculum is the analysis of the graduate's activities (qualification upon graduation). Therefore, on the practical level, based on the 30 laws, one could design curriculum for constructing " engineering systems thinking" and show on which learning theories or combination of theories should the learning environment be based.

Comments from DRDC reviewer:

The author provides a number of definitions and re-uses concepts from Senge (1994) and Senge et al., (1994) to derive 30 engineering Systems Thinking laws.

Scientific document: Systems Thinking for Defence Strategic Planning (Hodge, 2000)

Author(s):

Richard Hodge

Theatre Operations Branch, Defence Science & Technology Organization, Australia.

From the web site:

http://www.unisa.edu.au/seec/research/summaries_curr/richard%20hodge.asp:

Traditional Defence processes of triennial strategic assessments and septennial 'Defence White Papers' are used – as in many enterprises – to provide strategic direction in a continuously changing environment. In the late 1980s, the changes in global politics, economics, and technology impacted on Defence (and every other enterprise) to a point where, by 2000, traditional methods for strategic planning are no longer adequate. These changes provided the focus for the research question of this project: How can systems thinking and systems engineering principles be applied to Defence strategic planning to make it capable of defining Defence needs, requirements and priorities at any point in time while still presenting a view of those priorities over time. The research work involved literature research from commercial sources and business schools to establish that a solution for them remains elusive and little or no recognition has been given to the potential value in linking systems engineering and management schools of thought.

The project developed a theoretical model and an experimental 'model-test-model' approach incorporating seminar gaming to create a strategic functional architecture to guide decision-making on Defence capabilities. The resulting architecture offers benefits in two directions: (1) up, to the Government in making strategic trade-offs from given Defence resources, and (2) down, inside Defence to guide capability trade-offs in creating capability solutions matched to Government needs.

Scientific document: Systems Thinking for Joint Force Capability Planning and Management (Matthews et al., 2001)

Author(s):

David Matthews, Martin Burke, Phil Collier

Joint Systems Branch, DSTO, PO Box 1500 Salisbury, South Australia, 5108

Stephen Cook

Systems Engineering and Evaluation Centre, University of SA, Mawson Lakes, South Australia, 5095

From the document:

Joint Forces are anticipated to play an increasingly important role in the Australian Defence Organisation. This paper provides a way of thinking about Joint Forces intended to support activities such as Joint Force capability planning and management. The central approach is that of systems thinking. This approach is applied to develop a set of core concepts associated with strategic planning for future capabilities. In particular the idea of a portfolio is introduced as a management tool for future capability planning. The concepts developed are presented as elements within a system of ideas designed for the activities of long term planning for Australia's Joint Force capabilities and the assessment and day-to-day management of these capabilities.

Scientific document: Systems Thinking for Managing Projects (Mawby and Stupples, 2001)

Author(s):

Dave Mawby (david.mawby@paconsulting.com)

David Stupples

PA Consulting Group, 123 Buckingham Palace Road, London, SW1W 9SR, United Kigdom

From the document:

Systems thinking is a discipline that has been around for several decades now but most project managers remain ignorant of the potential power of some of the associated techniques in helping analyse, refine and deliver their complex projects. In fact, over the past 30 years more than 300

of the world's largest and most complex projects have successfully used the technology to improve the project outcome. Traditionally, a time-consuming technique to implement, it has only been utilised for the most complex projects. However, these methods are fast becoming more accessible and affordable for large projects in general. Applications of the technique have included project strategy formulation, change management, risk assessment and dispute resolution. Through modelling the rework cycle and the feedback loops that drive it, using system dynamics it is possible to analyse and hence improve the dynamic behaviour of our projects. In this paper we show how a system dynamics model of a project is constructed and used to assess project outcome. Examples of its application include: cost versus schedule trade-offs, project improvement strategies, risk assessment and risk mitigation strategies. The ability to deliver such answers quickly and accurately during the bid and project definition phases provides the project management team with a powerful decision making tool for project strategy formulation. The improvement in project outcome that can be achieved at this stage of the project is massive because of the low cost of change combined with a high leverage into project commitment, risk mitigation and outcome that is available at this stage in a project's lifecycle.

Comments from DRDC reviewer:

The authors re-use many of the concepts presented by Checkland (Checkland, 1999a, 1999b) to show how system dynamics allows the improvement of dynamics and behaviours of projects. They give a description of what is meant by complexity in project management and they identify a number of causes. Their work aims at lowering late costly “re-work” in project development.

Book: Thought as a System (Bohm, 1994)

Author(s):

David Bohm

From Amazon.com:

In Thought as a System, best-selling author David Bohm takes as his subject the role of thought and knowledge at every level of human affairs, from our private reflections on personal identity to our collective efforts to fashion a tolerable civilization. Elaborating upon principles of the relationship between mind and matter first put forward in Wholeness and the Implicate Order, Professor Bohm rejects the notion that our thinking processes neutrally report on what is `out there' in an objective world. Bohm carefully explores the manner in which thought actively participates in forming our perceptions, our sense of meaning and our daily actions. He suggests that collective thought and knowledge have become so automated that we are in large part controlled by them, with a subsequent loss of authenticity, freedom and order. In conversations with fifty seminar participants in Ojai, California, David Bohm offers a radical perspective on an underlying source of human conflict and inquires into the possibility of individual and collective transformation.

Book: Systems Thinking: Managing Chaos and Complexity: A Platform for Designing Business Architecture (Gharajedaghi , 1999)

Author(s):

Jamshid Gharajedaghi

From Amazon.com:

Discusses systems, the imparatives of interdependency, and the necessity of reducing endless complexities. Softcover. DLC: System analysis. "This is an excellent addition to books written on Systems Thinking. It is practical and timely and can be used by a vast majority of professionals such as engineers, planners and managers. I recommend it very highly to practitioners and academics." C. J. Khisty, Dept. of Civil Engineering, Illinois Institute of Technology. In a nutshell, this book is about systems. This book is written for those thinkers and practitioners who have come to realize that while the whole is becoming more and more interdependent parts display choice and behave independently, and that paradoxes are the most potent challenge of emergent realities. With a practical orientation and yet a profound theoretical depth, the book offers an operational handle on the whole by introducing an elaborate scheme called iterative design. The iterative design explicitly recognizes that choice is at the heart of human development. Development is the capacity to choose; design is a vehicle for enhancement of choice and holistic thinking. 'Designers', in this book, seek to choose rather than predict the future. They try to understand rational, emotional, and cultural dimensions of choice and to produce a design that satisfies a multitude of functions. They learn how to use what they already know and also about how to learn what they need to know. The imperative of interdependency, the necessity of reducing endless complexities, and the need to produce manageable simplicities require a different mode of thinking, a holistic frame of reference that would allow us to focus on the relevant issues and avoid the endless search for more details while drowning in proliferating information. While organizations as a whole are becoming more and more interdependent the parts display choice and behave independently. This is the dilemma this book tries to resolve. It is a unique, cutting edge work, with a practical orientation and yet a profound theoretical depth, which goes far beyond what is currently available. Leading edge systems thinking and practice that goes far beyond what is currently available. It deals with the whole, both conceptually and practically, written in a reader-friendly style. Five real cases cited to demonstrate practical application of theories discussed.

Comments from DRDC reviewer:

This book introduces a new way of thinking for analysing systems; the Systems Thinking. Many useful concepts allowing a better understanding of complex systems' behaviour are presented.

<u>Book</u>: Systems Thinking, Systems Practice; Includes a 30-Year Retrospective (Checkland , 1999a)

Author(s):

Peter Checkland

From Amazon.com:

Systems Thinking, Systems Practice "Whether by design, accident or merely synchronicity, Checkland appears to have developed a habit of writing seminal publications near the start of each decade which establish the basis and framework for systems methodology research for that

decade." Hamish Rennie, Journal of the Operational Research Society, 1992 Thirty years ago Peter Checkland set out to test whether the Systems Engineering (SE) approach, highly successful in technical problems, could be used by managers coping with the unfolding complexities of organizational life. The straightforward transfer of SE to the broader situations of management was not possible, but by insisting on a combination of systems thinking strongly linked to real-world practice Checkland and his collaborators developed an alternative approach - Soft Systems Methodology (SSM) - which enables managers of all kinds and at any level to deal with the subtleties and confusions of the situations they face. This work established the now accepted distinction between 'hard' systems thinking, in which parts of the world are taken to be 'systems' which can be 'engineered', and 'soft' systems thinking in which the focus is on making sure the process of inquiry into real-world complexity is itself a system for learning. Systems Thinking, Systems Practice (1981) and Soft Systems Methodology in Action (1990) together with an earlier paper Towards a Systems-based Methodology for Real-World Problem Solving (1972) have long been recognized as classics in the field. Now Peter Checkland has looked back over the three decades of SSM development, brought the account of it up to date, and reflected on the whole evolutionary process which has produced a mature SSM. SSM: A 30-Year Retrospective, here included with Systems Thinking, Systems Practice closes a chapter on what is undoubtedly the most significant single research programme on the use of systems ideas in problem solving. Now retired from full-time university work, Peter Checkland continues his research as a Leverhulme Emeritus Fellow.

Comments from DRDC reviewer:

The DRDC reviewer did not read this book but remarked that it is often referred in other scientific publications. This book appears to be a classic in the scientific literature.

Book: Soft Systems Methodology in Action (Checkland , 1999b)

Author(s):

Peter Checkland

From Amazon.com:

Soft Systems Methodology in Action "Whether by design, accident or merely synchronicity, Checkland appears to have developed a habit of writing seminal publications near the start of each decade which establish the basis and framework for systems methodology research for that decade." Hamish Rennie, Journal of the Operational Research Society, 1992 Thirty years ago Peter Checkland set out to test whether the Systems Engineering (SE) approach, highly successful in technical problems, could be used by managers coping with the unfolding complexities of organizational life. The straightforward transfer of SE to the broader situations of management was not possible, but by insisting on a combination of systems thinking strongly linked to real-world practice Checkland and his collaborators developed an alternative approach - Soft Systems Methodology (SSM) - which enables managers of all kinds and at any level to deal with the subtleties and confusions of the situations they face. This work established the now accepted distinction between 'hard' systems thinking, in which parts of the world are taken to be 'systems' which can be 'engineered', and 'soft' systems thinking in which the focus is on making sure the process of inquiry into real-world complexity is itself a system for learning. Systems Thinking,

Systems Practice (1981) and Soft Systems Methodology in Action (1990) together with an earlier paper Towards a Systems-based Methodology for Real-World Problem Solving (1972) have long been recognized as classics in the field. Now-Peter Checkland has looked back over the three decades of SSM development, brought the account of it up to date, and reflected on the whole evolutionary process which has produced a mature SSM. SSM: A 30-Year Retrospective, here included with Soft Systems Methodology in Action closes a chapter on what is undoubtedly the most significant single research programme on the use of systems ideas in problem solving. Now retired from full-time university work, Peter Checkland continues his research as a Leverhulme Emeritus Fellow.

From The publisher, John Wiley & Sons:

Finding better ways of coping with the complexity of human affairs is not an easy task. Due to its very nature, dealing with these problems requires flexibility and understanding to reach the best possible solution. This work grew out of the failure of established methods of systems engineering to adequately address and solve increasingly complex situations. The aim here is to provide a mature account of soft systems methodology (SSM) showing how it can offer the best possible ways of finding practical solutions that will benefit all those involved. Among the topics covered are: SSM and how it can be applied to different contexts; SSM in the creation of information systems; learning through the use of SSM in action; SSM in an organizational change program; using SSM in the national health service and civil service arena; and the practical applications of SSM in industry. --This text refers to an out of print or unavailable edition of this title.

Comments from DRDC reviewer:

The DRDC reviewer did not read this book but remarked that it is often referred in other scientific publications. This book appears to be a classic in the scientific literature.

<u>Book</u>: An Introduction to General Systems Thinking (Silver Anniversary) (Weinberg, 2001)

Author(s):

Gerald M. Weinberg

From Amazon.com:

For more than twenty-five years, An Introduction to General Systems Thinking has been hailed as an innovative introduction to systems theory, with applications in computer science and beyond. Used in university courses and professional seminars all over the world, the text has proven its ability to open minds and sharpen thinking. Originally published in 1975 and reprinted more than twenty times over a quarter century -- and now available for the first time from Dorset House Publishing -- the text uses clear writing and basic algebraic principles to explore new approaches to projects, products, organizations, and virtually any kind of system. Scientists, engineers, organization leaders, managers, doctors, students, and thinkers of all disciplines can use this book to dispel the mental fog that clouds problem-solving. As author Gerald M. Weinberg writes in the new preface to the Silver Anniversary Edition, "I haven't changed my conviction that most people don't think nearly as well as they could had they been taught some

principles of thinking." Now an award-winning author of nearly forty books spanning the entire software development life cycle, Weinberg had already acquired extensive experience as a programmer, manager, university professor, and consultant when this book was originally published. With helpful illustrations, numerous end-of-chapter exercises, and an appendix on a mathematical notation used in problem-solving, An Introduction to General Systems Thinking may be your most powerful tool in working with problems, systems, and solutions.

Comments from DRDC reviewer:

The DRDC reviewer did not read this book but remarked that it is often referred in other scientific publications. This book appears to be a classic in the scientific literature.

3 Complexity and Chaos Theory

3.1 Related State-of-the-Arts

<u>Scientific document</u>: État de l'art sur les theories de la décision et méthodologies de l'approche système (Montmain and Penalva, 2003)

Author(s):

Jacky Montmain

Commissariat à l'énergie Atomique

Jean Michel Penalva

École des mines d'Ales

Comments from DRDC reviewer:

This document is a state-of-the-art on theories related to "complex decision making" using systemic approaches.

<u>Scientific document</u>: Cognitive Complexity in Air Traffic Control - A Literature Review (Hilburn, 2004)

Author(s):

B. Hilburn (STASYS)

Eurocontrol Experimental Center

From the document:

This report reviews literature into air traffic control complexity. This work was carried out in the context of the Complexity and Capacity (COCA) project. This work reviewed past research (both theoretical and empirical) into ATC complexity, and its relationship to controller workload. In reviewing the forty-plus year history of work into ATC complexity, this effort identified:

- *The major theoretical views concerning ATC complexity.*
- *Candidate complexity factors.*
- *Data collection methods for identifying, refining and validating a model of ATC cognitive complexity.*

On the basis of this review, a functional model of ATC cognitive complexity is proposed that can help guide the next phase of the COCA work.

The overriding conclusion from this review was that despite the breadth and depth of previous work done into identifying ATC complexity factors, a good deal of work remains. Nobody, it seems, has yet managed to construct a valid and reliable model of ATC complexity that: 1. moves substantially beyond the predictive value of simple traffic density alone, and 2. is sufficiently context-free.

Further, it is proposed that COCA explore the development of nonlinear techniques to refine and develop its model of cognitive complexity.

Comments from DRDC reviewer:

The work done regarding the "complexity aspects" in this field (Air Traffic Control) may often be reused in other fields. Examples are: the complexity of operations and the perception and the comprehension (visual aspects) of complex situations under high stress conditions.

<u>Scientific document</u>: Complexity and Automation. Display of Air Traffic Control: Literature Review and Analysis (Xing and Manning, 2005)

Author(s):

Jing Xing and Carol A. Manning

Civil Aerospace Medical Institute, Federal Aviation Administration, Oklahoma City, OK 73125

From the document:

This report reviewed a number of measures of complexity associated with visual displays and analysed the potential to apply these methods to assess the complexity of air traffic control (ATC) displays. Through the literature review, we identified three basic complexity factors; numeric size, variety, and rules. Essentially, all the complexity measures could be described by these factors. Through the analysis of available complexity measures, we showed that neither information complexity that focused on the system not cognitive complexity that aimed at observers could provide a complete description for ATC application. The great variety in complexity measures reflected the fact that the contribution of each of these factors to overall complexity depended on how information is processed by users. We generalized that complexity is the integration of the observer with the three basic factors. Therefore, to develop objective complexity measures for ATC displays, the methods presented in this report need to be integrated with the ATC display specifications.

Comments from DRDC reviewer:

The authors present a review of literature which is oriented toward the measure of complexity for human-machine interface in Air Traffic Control (ATC) applications. This paper should be read by people in charge of developing visualization technologies. The study aims at finding ways of improving the perception operators have of the complexity while managing civilian air traffic. The concept of complexity is multi-dimensional and cannot be sufficiently described with a single measure. The authors identify many forms of complexity. They review complexity measures and methods with the perspective of Air Traffic Control applications. They evaluate the relevance of

each measure and methods in the context of the management of air traffic. Many of the conclusions can be directly applied for military-like application because used software and contexts of operations are relatively similar (high level of stress, huge amount of information, limited amount of time to process all the information and to make decisions, etc).

Scientific document: Complex Systems: Challenges and Opportunities. An orientation paper for Complex Systems research in FP7 (ONCE-CS, 2006)

Author(s):

A list of 53 contributors: Karl Aberer, Erik Aurell, Ozalp Babaoglu, Christopher Barrett, Pierre Bessière, Paul Bourgine, Guido Caldarelli, Luca Cardelli, John Casti, Michel Cotsaftis, Fabrizio Davide, Kemal Delic, Yves Demazeau, Jean-Louis Deneubourg, Tom Dhaene, Marco Dorigo, Gusz Eiben, Dario Floreano, Robert Ghanea-Hercock, Nigel Gilbert, Seif Haridi, David Hales, José Halloy, Dirk Helbing, Petter Holme, Jeffrey Johnson, François KÉPÈS, Anne-Marie Kermarrec, Scott Kirkpatrik, Imre Kondor, David Lane, Stefano Leonardi, Fumiya Lida, Vittorio Loreto, José Luiz Fiadeiro, Dominique Luzeaux, Enzo Marinari, Emmanuel Mazer, John McCaskill, Karlheinz Meier, Friedhelm Meyer-auf-der-Heide, Juan-Manuel Moreno-Aróstegui, Chrystopher Nehaniv, Stefano Nolfi, Norman Packard, Rolf Pfeifer, Corrado Priami, Mario Rasetti, David Saad, Jakka Sairamesh, Roberto Serra, Mikhail Smirnov, Ricard Solé, Pavlos Spirakis, Luc Steels, John Sutcliffe-Braithwaite, Eörs Szathmáry, John Taylor, Sergi Valverde, Gerhard Weikum, Gerard Weisbuch, Franco Zambonelli, Riccardo Zecchin.

Responsible for the document: David Chavalarias (http://chavalarias.free.fr/)

The Open Network of Centers of Excellence in Complex Systems (ONCE-CS)

From the web site:

ONCE-CS will maintain a Living Roadmap for Complex Systems Science, giving the state-of-the-art and the view of the community of where the science is going, and what its likely applications will be.

ONCE-CS will aim to serve the research community through its activities, including:

- *providing information on Complex Systems events*
- *organising conferences and meetings*
- *building an archive of CS literature on the web site*
- *working with the European Complex Systems Society*

From the document

The report is based on contributions from more than 60 researchers, each of whom identified key social, technological and scientific issues of the 21st century driven by information technologies which, they believe, can be addressed adequately only through novel approaches based on "complex systems" thinking. Each contribution was roughly structured around the following points: The challenges and visions: What are the obstacles faced by S&T and society today? Why

do current approaches fail? What are future pathways for IT? Why and how would Complex Systems research provide solutions? What differentiates complex systems research and methodologies from other more traditional approaches? The present report -edited by Mark Buchanan and Ralph Dum – is an attempt to synthesize this input and to identify the major topics that emerged from this consultation. This report is intended to stimulate discussions between stakeholders in research and in applications. It will be taken as a starting point for a continuous consultation of the interested community and is supposed to serve as input for funding agencies willing to address head-on challenges faced by science, society, and technology, in particular IT, today. The report is lacking – at this stage – milestones and benchmarks of progress that would help to quantify the potential contribution of complex systems research. A future version of this document must contain specific scenarios for where Complex systems research and information technologies are going and what its contributions to solving challenges of the 21st century on different time horizons could be – Milestones at 5 year, 10 year or even longer-term. To this end the coordination action ONCE-CS has set up an online consultation forum.

While IT is often the cause of increased complexity in designed systems, it also offers novel solutions for coping with such complexity. In particular, computer-based simulation offers a way to probe complex problems in an experimental fashion, often enabling the discovery of solutions that could be found in no other way. In business, for example, simulation-based exploration of complex and seemingly intractable problems has shown how flow of goods can be optimised by travelling along seemingly haphazard routes, or how manufacturing machines, if designed to "negotiate" with one another, can discover smooth operating schedules that no human mind would ever have imagined. In areas as diverse as engineering, physics, biology and social science, computer based simulation has allowed researchers to build artificial worlds in which solutions can be tested under realistic conditions before they ever face real world challenges. Europe will need greatly increased funding in ICT R&D from both public and private sources if it is to meet its economic and social objectives. However, to derive the greatest social benefit from its investment, the European Union also needs to address the most immediate and formidable roadblocks in ICT, the foremost of which is exploding system complexity. The demands of complexity will not go away. Engineers are beginning to acknowledge that traditional approaches are reaching limits of technological and computational feasibility. Complexity science offers the tools to confront these challenges head on, by emphasizing a shift from purely logic-based rational design to a distributed design approach harnessing capacity of self-organisation that is adapted to the natural complexity and changeability of the real world, both natural and man made. Europe is well placed to lead the way into this new era of science and engineering. It can base such a move on a strong base in mathematics, computer science, control theory, and physics as well as on a community of researchers willing to cross disciplinary boundaries in order to set the stage for tomorrow's approaches in scientific discovery, in engineering and in management and innovation. Information and communication technologies will play a central role in all these efforts as enablers of novel approaches in science and technology.

Despite the urgent needs and great opportunities offered by complex system science, there is still reluctance to accept that a radical change in mindset and novel approaches will be necessary. The strategic importance of this field is not recognized either at the level of funding agencies or on the level of organisational structures of research, engineering and in particular educational planning. Traditional boundaries still inhibit the development of an effective research agenda of complex systems. Therefore, a more systematic approach is needed to ensure encouragement of

the necessary long-term research on conceptual foundations. Only a Europe wide effort can lead the way to induce the necessary changes in the organisational structure of research can lead to the changes necessary in education of tomorrow's engineers and scientists. In the following pages key research areas will be identified where a complex system approach is crucial for further progress some of them are:

- *Internet and P2P networks: collective search engines*
- *Semantic interoperability in autonomous and heterogeneous systems*
- *Deeper understanding of the evolving characteristics and topology of the Internet*
- *Security in open networks*
- *Robotics: collective robotics, understanding of symbolic grounding*
- *Novel hardware architectures: resilient architectures, high plasticity architectures*
- *Novel paradigms for Software development as a collaborative design process.*
- *Modelling the brain and the brain-inspired novel computer architectures.*
- *Computer Science for systems biology – multi-cellularity as a computing paradigm.*
- *Micro to macro simulation of social and business processes; business ecosystems.*
- *Fundamental mathematics of complex systems as multilevel systems.*

Comments from DRDC reviewer:

This important paper presents a review of the complexity problems and needs in many domains. It shows how the Complexity Theory may (and probably will) bring significant improvements in many of these domains during the next years. It first introduces some challenges associated to our current and future complex world. Some common features of complex systems are identified. Many needs and opportunities are identified in specific strategic areas. The paper ends by giving more details on potential key methodologies and concepts that could help address complex problems in areas such as: the discovery of meaning in uncertain data, the scalability of complex systems, the understanding and the engineering of emergence, the science of complex networks, the modeling as a key in complexity science, the computational complexity, the economics and social sciences and the reconstruction of complex systems (inverse problems). The information contained in this paper often applies to many different domains as the complexity. The solutions found in one specific domain may often be re-used in another domain with minimal adjustment.

<u>Scientific document</u>: Complexity: An Overview of its Nature and Manifestations, and of S&T Convergence, with Comments on their Relevance to Canadian Defense (Poussart, 2006)

Author(s):

Denis Poussart

Université Laval

Comments from DRDC reviewer:

Dr Poussart presents an overview of many concepts from the Complexity Theory and makes useful links with S&T and other concrete concerns. This document is among the first ones to be read.

3.2 Complexity Theory

Scientific document: Dynamics, Computation, and the "Edge of Chaos": A Re-Examination (Mitchell et al., 1993)

Author(s):

Melanie Mitchell, James P. Crutchfield and Peter T. Hraber

Santa Fe Institute, 1399 Hyde Park Road, Santa Fe, NM 87501

http://www.santafe.edu/

From the paper:

In this paper we review previous work and present new work concerning the relationship between dynamical systems theory and computation. In particular we review work by Langton and Packard on the relationship between dynamical behavior and computational capability in cellular automata (Cas). We present results from an experiment similar to the one described by Packard which was cited as evidence for the hypothesis that rules capable of performing complex computations are most likely to be found at a phase transition between ordered and chaotic behavioral regimes for CAs the edge of chaos. Our experiment produced very different results from the original experiment and we suggest that the interpretation of the original results is not correct. We conclude by discussing general issues related to dynamics computation and the edge of chaos in cellular automata.

Scientific document: Investigations – The Nature of Autonomous Agents and the Worlds they Mutually Create (Kauffman, 1996)

Author(s):

Stuart A. Kauffman

From the paper:

The following document is being published as a Santa Fe Institute Preprint. The material below is not yet science. However, it is serious "protoscience" -- an attempt to formulate questions and concepts that may, in due course, become serious science. I take the step of informal publication for two major reasons: archival and collegial. It seems sensible to publish, in a restricted venue, the results of these efforts, to set them out in a rough and ready way. The topic appears to me to be very large, and is likely to require the efforts of many scholars to bring the protoscience to the stage of real science. In view of the recent exciting if tentative evidence for life on early Mars, and the first example of an autocatalytic peptide, attempts to understand the character of autonomous agents and the worlds they make seems especially appropriate.

Comments from DRDC reviewer:

This is a classical study on autonomous agents and Complex Adaptive Systems.

<u>Scientific document</u>: Eigenbehavior and Symbols (Rocha, 1996)

Author(s):

Luis Mateus Rocha

From the paper:

In this paper I sketch a rough taxonomy of self-organization which may be of relevance in the study of cognitive and biological systems. I frame the problem both in terms of the language Heinz von Foerster used to formulate much of second-order cybernetics as well as the language of current theories of self-organization and complexity. In particular, I defend the position that, on the one hand, self- organization alone is not rich enough for our intended simulations, and on the other, that genetic selection in biology and symbolic representation in cognitive science alone leave out the very important (self-organizing) characteristics of particular embodiments of evolving and learning systems. I propose the acceptance of the full concept of symbol with its syntactic, semantic, and pragmatic dimensions. I argue that the syntax should be treated operationally in second-order cybernetics.

Comments from DRDC reviewer:

Even if it is old, this is an interesting paper as it uses the concept from the principal component analysis to express the behaviours of complex systems.

<u>Scientific document</u>: The New Science of Complexity (McCauley, 2000)

Author(s):

Joe McCauley

From the document:

Deterministic chaos, and even maximum computational complexity, have been discovered within Newtonian dynamics. Economists assume that prices and price changes can also obey abstract mathematical laws of motion. Sociologists and other postmodernists advertise that physics and chemistry have outgrown their former limitations, that chaos and complexity provide new holistic paradigms for science, and that the boundaries between the hard and soft sciences, once impenetrable, have disappeared like the Berlin Wall. Three hundred years after the deaths of Galileo, Descartes, and Kepler, and the birth of Newton, reductionism appears to be on the decline, with holistic approaches to science on the upswing. We therefore examine the evidence that dynamical laws of motion may be discovered from empirical studies of chaotic or complex phenomena, and also review the foundation of reductionism in invariance principle.

<u>Scientific document</u>: Complexity rising: From human beings to human civilization, a complexity profile (Bar-Yam, 2002a)

Author(s):

Yaneer Bar-Yam (yaneer@necsi.org)

New England Complex Systems Institute

<u>Scientific document</u>: Complex Philosophy (Gershenson, 2002a)

Author(s):

Carlos Gershenson (C.Gershenson@sussex.ac.uk)

School of Cognitive and Computer Sciences, University of Sussex.

From the document:

As science, knowledge, and ideas evolve and are increased and refined, the branches of philosophy in charge of describing them should also be increased and refined. In this work we try to expand some ideas as a response to the recent approach from several sciences to complex systems. Because of their novelty, some of these ideas might require further refinement and may seem unfinished1 , but we need to start with something. Only with their propagation and feedback from critics they might be improved. We make a brief introduction to complex systems, for then defining abstraction levels. Abstraction levels represent simplicities and regularities in nature. We make an ontological distinction of absolute being and relative being, and then discuss issues on causality, metaphysics, and determinism.

<u>Scientific document</u>: Complex Systems Theory and Evolution (Mitchell, 2003)

Author(s):

Melanie Mitchell

Santa Fe Institute, 1399 Hyde Park Road, Santa Fe, NM 87501

http://www.santafe.edu/

<u>Scientific document</u>: Modeling the Emergence of Complexity: Complex Systems, the Origin of Life and Interactive On-Line Art (Sommerer and Mignonneau, 2002)

Author(s):

Christa Sommerer (artist), ATR Media Information Science Laboratories, 2–2 Hikaridai, Seika-cho, Soraku-gun, 6190288 Kyoto, Japan; Institute of Advanced Media Arts and Sciences, 3 –95 Ryoke-cho, Ogaki-shi, Gifu 503–0014, Japan. E-mail: <christa@atr.co.jp>.

Laurent Mignonneau (artist), ATR Media Information Science Laboratories, 2 –2 Hikaridai, Seika-cho, Soraku-gun, 6190288 Kyoto, Japan; Institute of Advanced Media Arts and Sciences, 3 –95 Ryoke-cho, Ogaki-shi, Gifu 503–0014, Japan. E-mail: <laurent@atr.co.jp>.

Comments from DRDC reviewer:

This is an interesting paper as it relates concepts from the Complexity Theory to arts. A good review of Life Theories and Complex Theory is made. Some properties and characteristics of complex systems are then presented. They also present different definitions of complex systems. They then introduce an interactive system for the Internet that enables on-line users to create 3D shapes by sending text messages to the VERBARIUM web site. Using their text-to-form editor, this system translates the text parameters into design parameters for the creation and modulation of 3D shapes. These shapes can become increasingly complex as users interact with the system.

Scientific document: Multiscale Variety in Complex Systems (Bar-Yam, 2004b)

Author(s):

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http://necsi.org/faculty/bar-yam.html

Scientific document: How can we think the complex? (Gershenson and Heylighen, 2005)

Author(s):

Carlos Gershenson (cgershen@ vub.ac.be)

Francis Heylighen (fheyligh@vub.ac.be)

Centrum Leo Apostel, Vrije Universiteit Brussel, Krijgskundestraat 33. B-1160 Brussels, Belgium,

http://www.vub.ac.be/CLEA.

From the document:

This chapter does not deal with specific tools and techniques for managing complex systems, but proposes some basic concepts that help us to think and speak about complexity. We review classical thinking and its intrinsic drawbacks when dealing with complexity. We then show how complexity forces us to build models with indeterminacy and unpredictability. However, we can

still deal with the problems created in this way by being adaptive, and profiting from a complex system's capability for selforganization, and the distributed intelligence this may produce.

Scientific document: **Unifying Principles in Complex Systems (Bar-Yam, 2006a)**

Author(s):

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http://necsi.org/faculty/bar-yam.html

Comments from DRDC reviewer:

This introduction paper presents some problems we are facing in this ever complex increasing world (*The failure of design and implementation of a new air-traffic control system[17], failures of Intel processors[18], medical errors[19,20], failures of medical drugs[21,22], even the failure of the Soviet Union, can be attributed to large system complexities*). The author presents the goal of complex systems research: *Understand the development and mechanisms of patterns of behavior and their use in Engineering; understand the way to deal with complex problems (engineering, management, economic, sociopolitical) with strategies that relate the complexity of the challenge to the complexity of the system that must respond to them; understand the unifying principles of organization, particularly for systems that deal with large amounts of information (physical, biological, social and engineered); understand the interplay of behaviors at multiple scales, and between the system and its environment; understand what is universal and what is not, when averaging applies and when it does not, what can be known and what cannot, what are the classes of universal behavior and the boundaries between them, and what are the relevant parameters for description or for affecting the behavior of the system; develop the ability to capture and represent specific systems, rather than just accumulate data about them. In this context: to describe relationships, know key behaviors, recognize relevance of properties to function, and to simulate dynamics and response; achieve a major educational shift toward unified understanding of systems, and patterns of system behavior.*

The author then states that *a theorem or principle of complex systems should apply to physical, biological, social and engineered systems. Laws in complex systems relate qualities of systems, action, environment, function and information*. He gives a definition of complexity that is based on the Law of Requisite Variety; *the larger the variety of actions available to a control system, the larger the variety of perturbations it is able to compensate (ref). Given a system whose function we want to specify, for which the environmental (input) variables have a complexity of C(e), and the actions of the system have a complexity of C(a), then the complexity of specification of the function of the system is: C(f) = C(a) 2C(e) where complexity is defined as the logarithm (base 2) of the number of possibilities or, equivalently, the length of a description in bits.*

The author then describe some potential research directions, they are:

- Understanding self-organization and pattern formation, and how it can be used to form engineered systems.
- Understanding description and representation.
- Understanding evolutionary dynamics.
- Understanding choices and anticipated effects: Games and agents.
- Understanding generic architectures.
- Understanding (recognizing) the paradoxes of complex systems.
- Developing systematic methodologies for the study of complex systems.

Scientific document: Introducing Complex Systems (Bar-Yam, 2006b)

Author(s):

Yaneer Bar-Yam (yaneer@necsi.org)

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http://necsi.org/faculty/bar-yam.html

Comments from DRDC reviewer:

This guide introduces many of the concepts related to complexity (relationship, emergence, interdependence, self-organization, pattern of behaviour, creativity, sub-division of networks, etc) and the simple and powerful perspectives of "complex systems". The author uses examples of system pertaining to biology and social sciences to introduce these concepts and to show how human can build their mental constructs in order to better understand complexity. He describes three interrelated approaches that are used in the modern study of complex systems; (1) how interactions give rise to patterns of behaviour, (2) the space of possibilities, and (3) the formation of complex systems through pattern formation and evolution. The author re-use Shannon's idea: *that messages in one language are longer or shorter than messages in a second language in a way that we can determine by counting the number of possible messages of a certain length* to show that the complexity of an object is related to the length of its description. He also states the importance of using the appropriate levels of details of descriptions (scale: measure of size used to determine level of detail provided in a description) to address specific level of complexity of problems. One of the conclusions he proposes is: *When parts are acting independently, the fine scale behavior is more complex. When they are working together the fine scale complexity is much smaller, but the behavior is a larger scale behavior" (…) " complexity is always a tradeoff, complex at a large scale means simple at a fine scale. This tradeoff is a basic idea that we need in order to understand complex systems*. The limits of hierarchical structures to address complex problems are then shown and compared with less hierarchical structures like networks.

<u>Scientific document</u>: Complexity and Philosophy (Heylighen et al., 2006)

Author(s):

Francis Heylighen

Evolution, Complexity and Cognition, Vrije Universiteit Brussel

Paul Cilliers

Philosophy Department, University of Stellenbosch

Carlos Gershenson

Evolution, Complexity and Cognition, Vrije Universiteit Brussel

From the document:

The science of complexity is based on a new way of thinking that stands in sharp contrast to the philosophy underlying Newtonian science, which is based on reductionism, determinism, and objective knowledge. This paper reviews the historical development of this new world view, focusing on its philosophical foundations. Determinism was challenged by quantum mechanics and chaos theory. Systems theory replaced reductionism by a scientifically based holism. Cybernetics and postmodern social science showed that knowledge is intrinsically subjective. These developments are being integrated under the header of "complexity science". Its central paradigm is the multi-agent system. Agents are intrinsically subjective and uncertain about their environment and future, but out of their local interactions, a global organization emerges. Although different philosophers, and in particular the postmodernists, have voiced similar ideas, the paradigm of complexity still needs to be fully assimilated by philosophy. This will throw a new light on old philosophical issues such as relativism, ethics and the role of the subject.

<u>Book</u>: Chaos (Gleick, 1989)

Author(s):

James Gleick

From Amazon.com

Few writers distinguish themselves by their ability to write about complicated, even obscure topics clearly and engagingly. James Gleick, a former science writer for the New York Times, resides in this exclusive category. In Chaos, he takes on the job of depicting the first years of the study of chaos--the seemingly random patterns that characterize many natural phenomena. This is not a purely technical book. Instead, it focuses as much on the scientists studying chaos as on the chaos itself. In the pages of Gleick's book, the reader meets dozens of extraordinary and eccentric people. For instance, Mitchell Feigenbaum, who constructed and regulated his life by a 26-hour clock and watched his waking hours come in and out of phase with those of his coworkers at Los Alamos National Laboratory. As for chaos itself, Gleick does an outstanding

job of explaining the thought processes and investigative techniques that researchers bring to bear on chaos problems. Rather than attempt to explain Julia sets, Lorenz attractors, and the Mandelbrot Set with gigantically complicated equations, Chaos relies on sketches, photographs, and Gleick's wonderful descriptive prose.

Comments from DRDC reviewer:

Gleick presents in this book a good historical overview of the origin of the Complexity Theory. Many references are made to classical experiments.

<u>Book</u>: Exploring Complexity (Nicolis and Prigogine, 1989)

Author(s):

Gregoire Nicolis and Ilya Prigogine

<u>Book</u>: Complexity: The Emerging Science at the Edge of Order and Chaos (Waldrop, 1992)

Author(s):

Mitchell Waldrop

From Publishers Weekly:

Waldrop presents his narrative of the "science of complexity in high screenplay style, offering a cast of five main characters. In general, he makes the emerging nature of complexity theory accessible to the general reader. He dissipates his advantage, however, in order to depict the personalities of the scientists he discusses, using at least three of them-Stuart Kauffman, Brian Arthur and Chris Langton-to act as interdisciplinary infielders of sorts, who relay the theory itself through a long subplot on structuring and funding the Santa Fe Institute in the 1970s. Complexity theory most likely will receive other, more rigorous examinations than Waldrop's, but he provides a good grounding of what may indeed be the first flowering of a new science. Copyright 1992 Reed Business Information, Inc. --This text refers to an out of print or unavailable edition of this title.

From Library Journal:

The Santa Fe Institute is an interdisciplinary think tank that has attracted the services of an electric and brilliant group of scholars. Here, economists work with biologists and physical scientists to develop theories that, many hope, will reveal that while natural systems may operate "at the edge of chaos," they are in fact self-organized. Thus conceived, the so-called science of complexity could explain the mysteries of how life began and might even predict global economic trends. The picture that emerges from this book, though, is that while many separate scientific endeavors overlap, a true conceptual

synthesis is still a long way away. Waldrop writes in a very readable, sometimes overly light and chatty style, but by focusing so strongly on individual efforts, he inadvertently supports the impression that what is called the unified science of complexity is conjectural and quite fragmented. While this book succeeds as a chronicle of the Santa Fe Institute, it does not fully convince the reader that complexity represents a scientific revolution.Optional for public libraries. Gregg Sapp, Montana State Univ. Libs., Bozeman

Comments from DRDC reviewer:

This book is often cited in the scientific literature.

Book: Complexity: Life at the Edge of Chaos (Lewin, 1993)

Author(s):

Roger Lewin

Comments from DRDC reviewer:

This book is often cited in the scientific literature.

Book: The Origin of Order (Kauffman, 1993)

Author(s):

Stuart Kauffman (stu.kauffman@worldnet.att.net)

http://www.santafe.edu/sfi/People/kauffman/

From Amazon.com

Stuart Kauffman here presents a brilliant new paradigm for evolutionary biology, one that extends the basic concepts of Darwinian evolution to accommodate recent findings and perspectives from the fields of biology, physics, chemistry and mathematics. The book drives to the heart of the exciting debate on the origins of life and maintenance of order in complex biological systems. It focuses on the concept of self-organization: the spontaneous emergence of order that is widely observed throughout nature Kauffman argues that self-organization plays an important role in the Darwinian process of natural selection. Yet until now no systematic effort has been made to incorporate the concept of self-organization into evolutionary theory. The construction requirements which permit complex systems to adapt are poorly understood, as is the extent to which selection itself can yield systems able to adapt more successfully. This book explores these themes. It shows how complex systems, contrary to expectations, can spontaneously exhibit stunning degrees of order, and how this order, in turn, is essential for understanding the emergence and development of life on Earth. Topics include the new biotechnology of applied molecular evolution, with its important implications for developing new drugs and vaccines; the balance between order and chaos observed in many naturally occurring

systems; new insights concerning the predictive power of statistical mechanics in biology; and other major issues. Indeed, the approaches investigated here may prove to be the new center around which biological science itself will evolve. The work is written for all those interested in the cutting edge of research in the life sciences.

Comments from DRDC reviewer:

This book is often cited in the scientific literature.

Book: At Home in the Universe: The Search for the Laws of Self-Organization and Complexity (Kauffman, 1995)

Author(s):

Stuart Kauffman (stu.kauffman@worldnet.att.net)

http://www.santafe.edu/sfi/People/kauffman/

From Amazon.com

A major scientific revolution has begun, a new paradigm that rivals Darwin's theory in importance. At its heart is the discovery of the order that lies deep within the most complex of systems, from the origin of life, to the workings of giant corporations, to the rise and fall of great civilizations. And more than anyone else, this revolution is the work of one man, Stuart Kauffman, a MacArthur Fellow and visionary pioneer of the new science of complexity. Now, in At Home in the Universe, Kauffman brilliantly weaves together the excitement of intellectual discovery and a fertile mix of insights to give the general reader a fascinating look at this new science--and at the forces for order that lie at the edge of chaos. We all know of instances of spontaneous order in nature--an oil droplet in water forms a sphere, snowflakes have a six-fold symmetry. What we are only now discovering, Kauffman says, is that the range of spontaneous order is enormously greater than we had supposed. Indeed, self-organization is a great undiscovered principle of nature. But how does this spontaneous order arise? Kauffman contends that complexity itself triggers self-organization, or what he calls "order for free," that if enough different molecules pass a certain threshold of complexity, they begin to self-organize into a new entity--a living cell. Kauffman uses the analogy of a thousand buttons on a rug--join two buttons randomly with thread, then another two, and so on. At first, you have isolated pairs; later, small clusters; but suddenly at around the 500th repetition, a remarkable transformation occurs--much like the phase transition when water abruptly turns to ice--and the buttons link up in one giant network. Likewise, life may have originated when the mix of different molecules in the primordial soup passed a certain level of complexity and self-organized into living entities (if so, then life is not a highly improbable chance event, but almost inevitable). Kauffman uses the basic insight of "order for free" to illuminate a staggering range of phenomena. We see how a single-celled embryo can grow to a highly complex organism with over two hundred different cell types. We learn how the science of complexity extends Darwin's theory of evolution by natural selection: that self-organization, selection, and chance are the engines of the biosphere. And we gain insights into biotechnology, the stunning magic of the new frontier of genetic engineering--generating trillions of novel molecules to find new drugs, vaccines, enzymes, biosensors, and more. Indeed, Kauffman shows that ecosystems, economic systems, and even cultural systems may

all evolve according to similar general laws, that tissues and terra cotta evolve in similar ways. And finally, there is a profoundly spiritual element to Kauffman's thought. If, as he argues, life were bound to arise, not as an incalculably improbable accident, but as an expected fulfillment of the natural order, then we truly are at home in the universe. Kauffman's earlier volume, The Origins of Order, written for specialists, received lavish praise. Stephen Jay Gould called it "a landmark and a classic." And Nobel Laureate Philip Anderson wrote that "there are few people in this world who ever ask the right questions of science, and they are the ones who affect its future most profoundly. Stuart Kauffman is one of these." In At Home in the Universe, this visionary thinker takes you along as he explores new insights into the nature of life.

Comments from DRDC reviewer:

This book is another classical in the scientific literature.

Book: The Systems View of the World: A Holistic Vision for Our Time (Laszlo, 1996)

Author(s):

Ervin Laszlo

Book: Essence of Chaos (Lorenz, 1996)

Author(s):

Edward N. Lorenz

Comments from DRDC reviewer:

The author takes a complicated topic and makes it accessible for all people, regardless of prior knowledge of chaos theory. The author gives a brief history of chaos and explains how it is used in the study of mathematics, meteorology, economics, music, and other fields. Easy to follow examples and a glossary are provided. Lorenz is a pioneer in the science of complexity and chaos.

Book: Chaos, An Introduction to Dynamical Systems (Alligood et al., 1996)

Author(s):

Kathleen T. Alligood, Tim D. Sauer, James A. Yorke

From G.J.G. Junevicus, Choice online

This exceptional introductory work is uniquely characterized by its combination of breadth and depth and by its pedagogical style of actively engaging the reader in exercises integral to theory development...The exposition is clear, solid, and well-illustrated.

From Amazon.com:

Chaos: An Intoduction to Dynamical Systems, was developed and class-tested by a distinguished team of authors at two universities through their teaching of courses based on the material. Intended for courses in nonlinear dynamics offered either in Mathematics or Physics, the text requires only calculus, differential equations, and linear algebra as prerequisites. Along with discussions of the major topics, including discrete dynamical systems, chaos, fractals, nonlinear differential equations and bifurcations, the text also includes Lab Visits, short reports that illustrate relevant concepts from the physical, chemical and biological sciences. There are Computer Experiments throughout the text that present opportunities to explore dynamics through computer simulations, designed to be used with any software package. And each chapter ends with a Challenge, which provides students a tour through an advanced topic in the form of an extended exercise. Develops and explains the most intriguing and fundamental elements of the topic, and examines their broad implications. Topics covered include discrete dynamical systems, chaos, fractals, nonlinear differential equations and bifurcations.

Book: **Unifying Themes in Complex Systems: Proceedings of the First International Conference on Complex Systems (Bar-Yam, 1997)**

Author(s):

Yaneer Bar-Yam and Ali Minai

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Book: **Chaos Theory Tamed (Williams, 2001)**

Author(s):

Garnett P. Williams

From Amazon.com:

Helps you understand the basic concepts of this relatively new arm of science. Drawing from mathematics, physics and statistics, this book provides a toolkit for readers, including, vectors, phase space, Fourier analysis, timeseries analysis, and autocorrection. Williams uses lists, graphics, examples, and friendly language to help readers understand the vocabulary and significance of chaos theory. The book will help scientists and students outside mathematics to use the concepts of chaos in working with data and will help interested lay readers grasp the fundamentals of chaos theory Pub: 9/97.

Comments from DRDC reviewer:

The content is relatively complete, well presented and the level is always appropriate. The book also contains a useful Glossary.

<u>Book</u>: The Computational Beauty of Nature: Computer Explorations of Fractals, Chaos, Complex Systems, and Adaptation (Flake , 1998)

Author(s):

Gary William Flake

From Jason R. Taylor, SB&F, May/June 1999:

This is a wonderful book. The author lucidly describes the computational beauty of nature from four different perspectives: `Computer Explorations,' `Chaos,'‘Complex Systems,' and `Adaptation,'... Using all four approaches, Flake not only clearly describes nature, but also presents the same phenomena with each approach. This strategy gives the reader a very broad-based educational experience and promotes critical thinking. Without such a presentation, explaining models that purport to describe `nature' can be quite intimidating. Flexibility is another major plus of this publication: Readers may skip a portion of any section or even an entire section without loss of continuity... reading this awe-inspiring book will be a colorful experience for the mind.

From Amazon.com:

In this book Gary William Flake develops in depth the simple idea that recurrent rules can produce rich and complicated behaviors. Distinguishing "agents" (e.g., molecules, cells, animals, and species) from their interactions (e.g., chemical reactions, immune system responses, sexual reproduction, and evolution), Flake argues that it is the computational properties of interactions that account for much of what we think of as "beautiful" and "interesting." From this basic thesis, Flake explores what he considers to be today's four most interesting computational topics: fractals, chaos, complex systems, and adaptation. Each of the book's parts can be read independently, enabling even the casual reader to understand and work with the basic equations and programs. Yet the parts are bound together by the theme of the computer as a laboratory and a metaphor for understanding the universe. The inspired reader will experiment further with the ideas presented to create fractal landscapes, chaotic systems, artificial life forms, genetic algorithms, and artificial neural networks. Contents include computation, fractals, chaos, complex systems, adaptation, genetics and evolution, cellular automata, controlling chaos, strange attractors, number systems and infinity, and more.

Comments from DRDC reviewer:

This is another interesting introductory book. The author covers many subjects, giving the reader a global view of complexity sciences.

Book: **Dynamics of Complex Systems (Bar-Yam, 1999)**

Author(s):

Yaneer Bar-Yam (yaneer@necsi.org)

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From Amazon.com

Describes the modern unified study of complex systems. Develops models and modeling techniques that are useful when applied to all complex systems. Discusses complex systems in the context of neural networks, protein folding, living organisms. DLC: Biomathematics.

Book: **Chaos, Fractals, and Dynamics: Computer Experiments in Mathematics (Devaney, 2000)**

Author(s):

Robert L. Devaney

Book: **Leadership and the New Science: Discovering Order in a Chaotic World Revised (Wheatley , 2001)**

Author(s):

Margaret J. Wheatley

From Amazon.ca:

When Margaret J. Wheatley's Leadership and the New Science was initially published in 1992, it outlined an unquestionably unique but extremely challenging view of change, leadership, and the structure of groups. Many readers immediately embraced its cutting-edge perspective, but others just could not understand how the complicated scientific tenets it described could be used to reshape institutions. Now Wheatley, an organizational specialist who has since coauthored A Simpler Way, updates the original by including additional material (such as an epilogue addressing her personal experiences during the past decade) and reconstructing some of her more challenging concepts. The result is a much clearer work that first explores the implications of quantum physics on organizational practice, then investigates ways that biology and chemistry affect living systems, and finally focuses on chaos theory, the creation of a new order, and the manner that scientific principles affect leadership. "Our old ways of

relating to each other don't support us any longer," she writes. "It is up to us to journey forth in search of new practices and new ideas that will enable us to create lives and organizations worthy of human habitation." --Howard Rothman --This text refers to an out of print or unavailable edition of this title.

In this revised edition of her 1992 book, Wheatley provides an overview of some dramatic changes in scientific thought, such as chaos theory and quantum physics, and then applies those theories to organizations. What kind of organizations? Organizations of all sizes and shapes and business. Wheatley reads her work competently, in a controlled, even voice. Her straightforward presentation offers few distractions and is easy listening. She integrates the theoretical with a range of practical examples from many of the organizations she has worked with. J.E.M. © AudioFile 2001, Portland, Maine--Copyright © AudioFile, Portland, Maine.

Book: Chaos in Dynamical Systems (Ott, 2002)

Author(s):

Edward Ott

From Amazon.com

From reviews of the previous edition: '... a stimulating selection of topics that could be taught a la carte in postgraduate courses. The book is given unity by a preoccupation with scaling arguments, but covers almost all aspects of the subject (dimensions of strange attractors, transitions to chaos, thermodynamic formalism, scattering quantum chaos and so on ... Ott has managed to capture the beauty of this subject in a way that should motivate and inform the next generation of students in applied dynamical systems.' Nature

From reviews of the previous edition: '... proves there is definitely enough worthwhile material on chaos to fill a semester ... Chapter exercises are at a good level for graduate students ... worthwhile for the researcher who wants to learn about chaos on his or her own ... a welcome volume for those who keep even modest collections on nonlinear dynamics.' Physics Today '... a book that will be of most interest to physicists and engineers ... The book is well written, and does contain material that is hard to find elsewhere. In particular, the discussion of fractal basin boundaries is lucidly written, and this is an important topic.' Bulletin of Mathematical Biology.

The most important change is the addition of a completely new chapter on control and synchronization of chaos. Other changes include new material on riddled basins of attraction, phase locking of globally coupled oscillators, fractal aspects of fluid advection by Lagrangian chaotic flows, magnetic dynamos, and strange nonchaotic attractors.

Book: Unifying Themes in Complex Systems Volume II (Bar-Yam, 2003a)

Author(s):

Yaneer Bar-Yam (yaneer@necsi.org)

New England Complex Systems Institute, 24 Mt. Auburn St., Cambridge, MA 02138, TEL 617-547-4100 FAX 617-661-7711, necsi@necsi.org, http://necsi.org/faculty/bar-yam.html

<u>Book</u>: Dynamics of Complex Systems (Bar-Yam, 2003b)

Author(s):

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http://necsi.org/faculty/bar-yam.html

From Amazon.com

Describes the modern unified study of complex systems. Develops models and modeling techniques that are useful when applied to all complex systems. Discusses complex systems in the context of neural networks, protein folding, living organisms.

<u>Book</u>: Unifying Themes in Complex Systems (Bar-Yam, 2003c)

Author(s):

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http://necsi.org/faculty/bar-yam.html

<u>Book</u>: Introduction to the Theory of Computation (Sipserss, 2005)

Author(s):

Michael Sipserss

From Amazon.com:

"Intended as an upper-level undergraduate or introductory graduate text in computer science theory," this book lucidly covers the key concepts and theorems of the theory of computation. The presentation is remarkably clear; for example, the "proof idea," which offers the reader an intuitive feel for how the proof was constructed, accompanies many of the theorems and a proof. Introduction to the Theory of Computation covers the usual

topics for this type of text plus it features a solid section on complexity theory--including an entire chapter on space complexity. The final chapter introduces more advanced topics, such as the discussion of complexity classes associated with probabilistic algorithms. --This text refers to the [Hardcover](#) edition.

<u>Book</u>: Making Things Work: Solving Complex Problems in a Complex World (Bar-Yam, 2005)

Author(s):

Yaneer Bar-Yam (yaneer@necsi.org)

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necsi@necsi.org

http://necsi.org/faculty/bar-yam.html

Comment from NECSI web Site:

Today, as individuals and as a society, we are faced with highly complex challenges. When we don't solve them correctly they rapidly become crises. This book explains how we can use complex systems research to solve complex problems in: ♦ healthcare ♦ education ♦ military conflict ♦ ethnic violence and terrorism ♦ international development. Highly complex problems cannot be solved by any one individual. Traditional organizations, traditional forms of control and planning are not effective. Making Things Work draws on insights from complex systems research about emergence, complexity, patterns, networks and evolution. It explains how effective organizations form through cooperation and competition, and how to make non-hierarchical distributed organizational structures effective at their tasks.

<u>Book</u>: An Introduction to Kolmogorov Complexity and Its Applications (Li and Vitanyi, 2005)

Author(s):

Ming Li and Paul Vitanyi

Comment from Amazon web site:

<u>The book is outstanding and admirable in many respects. ... is necessary reading for all kinds of readers from undergraduate students to top authorities in the field." Journal of Symbolic Logic Written by two experts in the field, this is the only comprehensive and unified treatment of the central ideas and their applications of Kolmogorov complexity. the book presents a thorough treatment of the subject with a wide range of illsutrative applications. Such applications include the randomeness of finite objects or infinite sequences, Martin-Loef tests for randomness, information theory, computationla learning theory, the complexity of algorithms, and the thermodynamics of computing. It will be ideal for advanced undergraduate students, graduate</u>

students, and researchers in computer science, mathematics, cognitive sciences, philosophy, artificial intelligence, statistics, and physics. the book is self-contained in that it contains the basic requirements from mathematics and computer science. Included are also numerous problem sets, comments, source references, and himnts to solutions of problems. In this new edition the authors have added new material on circuit theory, distributed algorithms, data compression, and other topics.

3.3 Complex Adaptive Systems

Scientific document: External and Internal Complexity of Complex Adaptive Systems (Jost, 2003)

Author(s):

Juergen Jost

Santa Fe Institute, 1399 Hyde Park Road, Santa Fe, NM 87501

http://www.santafe.edu/

From the document:

We introduce concepts of external and internal complexity to analyze the relationship between an adaptive system and its environment. We apply this theoretical framework to the construction of models in a cognitive system and the selection between hypotheses through selective observations performed on a data set in a recurrent process and propose a corresponding neural network architecture.

Comments from DRDC reviewer:

Interesting ideas are presented.

Scientific document: Complex Adaptive Systems (Lansing, 2003)

Author(s):

J. Stephen Lansing (jlansing@u.arizona.edu)

Department of Anthropology, 221 Haury Bldg., University of Arizona, Tucson, Arizona 85721-0030; external faculty, Santa Fe Institute, 1399 Hyde Park Road, Santa Fe, New Mexico 87501.

From the document:

The study of complex adaptive systems, a subset of nonlinear dynamical systems, has recently become a major focus of interdisciplinary research in the social and natural sciences. Nonlinear systems are ubiquitous; as mathematician Stanislaw Ulam observed, to speak of "nonlinear science" is like calling zoology the study of "nonelephant animals" (quoted in Campbell et al.

1985, p. 374). The initial phase of research on nonlinear systems focused on deterministic chaos, but more recent studies have investigated the properties of self-organizing systems or anti-chaos. For mathematicians and physicists, the biggest surprise is that complexity lurks within extremely simple systems. For biologists, it is the idea that natural selection is not the sole source of order in the biological world. In the social sciences, it is suggested that emergence—the idea that complex global patterns with new properties can emerge from local interactions—could have a comparable impact.

Comments from DRDC reviewer:

This paper should be read as introductory to the Complexity Theory.

Book: Hidden Order: How Adaptation Builds Complexity (Holland, 1995)

Author(s):

John H. Holland

Santa Fe Institute, 1399 Hyde Park Road, Santa Fe, NM 87501

http://www.santafe.edu/

Comments from DRDC reviewer:

The author provides a theoretical framework that can be used to examine questions like emergence and agent interactions. This book is a classic in the Complexity Theory.

Book: Emergence: from chaos to order (Holland, 1998)

Author(s):

John H. Holland

Santa Fe Institute, 1399 Hyde Park Road, Santa Fe, NM 87501

http://www.santafe.edu/

3.4 Features and Characteristics of Complex Adaptive Systems

3.4.1 Emergence

Scientific document: The Calculi of Emergence: Computation, Dynamics, and Induction (Crutchfield, 1994)

Author(s):

James P. Crutchfield

Physics Department, University of California, Berkeley, California 94720, USA

From the document:

Defining structure and detecting the emergence of complexity in nature are inherently subjective, though essential, scientific activities. Despite the difficulties, these problems can be analyzed in terms of how model-building observers infer from measurements the computational capabilities embedded in nonlinear processes. An observer's notion of what is ordered, what is random, and what is complex in its environment depends directly on its computational resources: the amount of raw measurement data, of memory, and of time available for estimation and inference. The discovery of structure in an environment depends more critically and subtlely, though, on how those resources are organized. The descriptive power of the observer's chosen (or implicit) computational model class, for example, can be an overwhelming determinant in finding regularity in data. This paper presents an overview of an inductive framework -- hierarchical ϵ-machine reconstruction -- in which the emergence of complexity is associated with the innovation of new computational model classes. Complexity metrics for detecting structure and quantifying emergence, along with an analysis of the constraints on the dynamics of innovation, are outlined. Illustrative examples are drawn from the onset of unpredictability in nonlinear systems, finitary nondeterministic processes, and cellular automata pattern recognition. They demonstrate how finite inference resources drive the innovation of new structures and so lead to the emergence of complexity.

Comments from DRDC reviewer:

This paper is often cited in the scientific literature.

<u>Scientific document</u>: Emergent behavior in biological systems (Green, 1994)

Author(s):

David G. Green (dgreen@csu.edu.au)

School of Environmental and Information Science, Charles Sturt University, PO Box 789, Albury, 2640, Australia

From the document:

Underlying many kinds of emergent behavior in biology are the critical changes in connectivity that occur, as links increase between the elements of a system. The behavior of systems with near-critical connectivity is essentially chaotic and may be an important source of variety in biology. In most models of biological systems (for example, dynamical systems, cellular automata, state spaces) the patterns of connectivity between elements are isomorphic to directed graphs. These isomorphisms suggest that the above sources of emergent behaviour may be universal.

<u>Scientific document</u>: On Complexity and Emergence (Standish, 2001)

Author(s):

Russell K. Standish (R.Standish@unsw.edu.au)

High Performance Computing Support Unit, University of New South Wales, http://parallel.hpc.unsw.edu.au/rks

From the document:

Numerous definitions for complexity have been proposed over the last half century, with little consensus achieved on how to use the term. A definition of complexity is supplied here that is closely related to the Kolmogorov Complexity and Shannon Entropy measures widely used as complexity measures, yet addresses a number of concerns raised against these measures. However, the price of doing this is to introduce context dependence into the definition of complexity. It is argued that such context dependence is an inherent property of complexity, and related concepts such as entropy and emergence. Scientists are uncomfortable with such context dependence, which smacks of subjectivity, and this is perhaps the reason why little agreement has been found on the meaning of these terms.

Comments from DRDC reviewer:

This paper gives a theoretical definition of complexity and emergence. The author is concerned with the context dependence of complexity and asks the question *Is complexity completely subjective? Is everything lost?* Rather than trying to hide this context dependence, he prefers to make it a feature. *Instead of asserting complexity is a property of some system, it is a property of descriptions (which may or may not be about a system).* He gives an interesting definition of emergence which is based on the scale used to describe systems (in terms of micro description and macro description). He says that *emergence is not due to the failure of the micro description as a modeling effort. An emergent phenomenon is simply one that is described by atomic concepts available in the macro language, but cannot be so described in the micro language. Of considerable interest is, given a system specified in its micro language, does it have emergent properties? There is no general procedure for answering this question. One has to construct a macro description of the system. If this macro description contains atomic concepts that are not simple compounds of micro concepts, then one has emergent properties*. Then the author makes some interesting parallels with the thermodynamic measure of disorder; entropy.

Scientific document: Emergence: Open Your Eyes to New Vistas (McConnell, 2001)

Author(s):

Georges R. McConnell (george.mcconnell@baesystems.com)

BAE Systems, Grange Road, Christchurch, Dorset, BH23 4JE, United Kingdom

From the document:

As Systems Engineers grapple with the problems of complex systems and, in particular the emergent behaviour, properties and capabilities which they exhibit, it becomes necessary to find

techniques which render these complex problems tractable. Using traditional methods often results in being unable to understand why the emergences happen, when they will occur or how to minimise their impact. This paper examines these problems and offers for consideration the idea that the most fundamental thing which must be done to cope with this difficulty is to view the systems from many different perspectives. It is particularly important to look at the contexts of the system and to investigate why the system may have to satisfy the, possibly conflicting, needs of different contexts.

<u>Scientific document</u>: Towards a theory of everything? – Grand challenges in complexity and informatics (Green and Newth, 2001)

Author(s):

David G. Green (dgreen@csu.edu.au)

David Newth (dnewth@csu.edu.au)

Environmental and Information Science, Charles Sturt University, PO Box 789, Albury, NSW, 2640 AUSTRALIA

From the document:

This account surveys some of the major developments in complexity research and proposes number of questions and issues for future research. The topics are organized into three areas.Under theory, we consider self-organisation, emergence, criticality, connectivity, as well as the paradigm of natural computation. Applications include several areas of science and technology where complexity plays a prominent part such as development, evolution, and global information.systems. Finally, under practice, we consider some of the issues involved in trying to develop a coherent methodology for dealing with complexity.

Comments from DRDC reviewer:

This paper gives an overview of many aspects of Complexity Theory and chaos. The authors pose appropriate questions like *how things organize themselves?* or *how do large-scale phenomena emerge from the simple components?*. They explain the role of connectivity in complex systems (and criticality) and make interesting links with Graph Theory. They use an example to explain the difference between “Edge of Chaos” and “Chaotic Edge”; two different models for studying phase change of systems. Finally, the authors bring some insights that could help building a unified framework to address complexity problems. One of them suggests how to make “transparent” measurements (the measure is not affected by the measuring process).

<u>Scientific document</u>: Evolution, Emergence and Learning in Complex Systems (Allen, 2002)

Author(s):

Peter M. Allen (p.m.allen@cranfield.ac.uk)

Complex Systems Management Center, Cranfield School of Management, Beds. MK43 OAL, England.

Scientific document: The Emergent Computational Potential of Evolving Artificial Living Systems (Wiedermann and Van Leeuwen, 2002)

Author(s):

Wiedermann, J. and J. van Leeuwen

From the document:

The computational potential of artificial living systems can be studied without knowing the algorithms that govern their behavior. Modeling single organisms by means of socalled cognitive transducers, we will estimate the computational power of AL systems by viewing them as conglomerates of such organisms. We describe a scenario in which an artificial living (AL) system is involved in a potentially infinite, unpredictable interaction with an active or passive environment, to which it can react by learning and adjusting its behaviour. By making use of sequences of cognitive transducers one can also model the evolution of AL systems caused by `architectural' changes. Among the examples are `communities of agents', i.e. by communities of mobile, interactive cognitive transducers.

Scientific document: Selection, Tinkering, and Emergence in Complex Networks (Solé et al., 2002)

Author(s):

Ricard V. Solé, Ramon Ferrer Cancho, Sergi Valverde, and José M. Montoya

Santa Fe Institute, 1399 Hyde Park Road, Santa Fe, NM 87501

http://www.santafe.edu/

From the document:

Complex biological networks have very different origins than technologic ones. The latter involve extensive design and, as engineered structures, include a high level of optimization. The former involve (in principle) contingency and structural constraints, with new structures being incorporated through tinkering with previously evolved modules or units. However, the observation of the topological features of different biological nets suggests that nature can have a limited repertoire of "attractors" that essentially optimize communication under some basic constraints of cost and architecture or that allow the biological nets to reach a high degree of homeostasis. Conversely, the topological features exhibited by some technology graphs indicate that tinkering and internal constraints play a key role, in spite of the "designed" nature of these structures. Previous scenarios suggested to explain the overall trends of evolution are re-analyzed in light of topological patterns.

Scientific document: Toward a Formalization of Emergence (Kubík, 2003)

Author(s):

Aleš Kubík

Institute of Computer Science, Silesian University, Bezrucovo nám. 13, 746 01 Opava, Czech Republic.

From the document:

Emergence is a concept widely used in the sciences, the arts, and engineering. Some effort has been made to formalize it, but it is used in various contexts with different meanings, and a unified theory of emergence is still distant. The ultimate goal of a theory of emergence should include using emergence to model, design, or predict the behavior of multiagent systems. The author proposes a formal definition of a basic type of emergence using a language-theoretic and grammar systems approach. It is shown which types of phenomena can be modeled in this sense and what the consequences are for other more complex phenomena.

Comments from DRDC reviewer:

This paper is often cited in the scientific literature.

Scientific document: Objects That Make Objects: The Population Dynamics of Structural Complexity (Crutchfield and Gornerup, 2004)

Author(s):

James P. Crutchfield and Olof Gornerup

Santa Fe Institute, 1399 Hyde Park Road, Santa Fe, NM 87501

http://www.santafe.edu/

From the document:

To analyze the evolutionary emergence of structural complexity in physical processes we introduce a general, but tractable, model of objects that interact to produce new objects. Since the objects—epsilon-machines—have well-defined structural properties, we demonstrate that complexity in the resulting population dynamical system emerges on several distinct organizational scales during evolution—from individuals to nested levels of mutually self-sustaining interaction. The evolution to increased organization is dominated by the spontaneous creation of structural hierarchies and this, in turn, is facilitated by the innovation and maintenance of relatively low-complexity, but general individuals.

Scientific document: On the Emergence of Complex Systems on the Basis of the Coordination of Complex Behavior of Their Elements (Atay and Juergen, 2004)

Author(s):

Fatihcan Atay and Juergen Jost

Santa Fe Institute, 1399 Hyde Park Road, Santa Fe, NM 87501

http://www.santafe.edu/

From the document:

We argue that the coordination of the activities of individual complex agents enables a system to develop and sustain complexity at a higher level. We exemplify relevant mechanisms through computer simulations of a toy system, a coupled map lattice with transmission delays. The coordination here is achieved through the synchronization of the chaotic operations of the individual elements, and on the basis of this, regular behavior at a longer temporal scale emerges that is inaccessible to the uncoupled individual dynamics.

Scientific document: System Thermodynamics: A Model Illustrating Complexity Emerging from Simplicity (Aslaksen, 2004)

Author(s):

Erik W. Aslaksen (elfierik@bigpond.net.au)

Sinclair Knight Merz, 100 Christie Street, St. Leonards NSW 2065, Australia

From the document:

A high-level model of a self-sustaining system exhibiting the life cycle phases of growth, survival, and decay is introduced. The model, which is anchored in thermodynamics, does not make any assumptions about the functionality or physical nature of the system, and only very general assumptions about the structure of the system and the processes involved in growth and decay. The central features of the model are that the interaction between the system and its environment depends on the match between the structures of the system and the environment and that the decay of the system is caused by fluctuations in this match. The relationship between fluctuations and lifespan is investigated through numerical simulation, and it is shown that the space spanned by fluctuation amplitude and mismatch tolerance is divided into a stable and an unstable region. An example of how the model might be applied is provided, and some extensions of the model are suggested.

Scientific document: A Mathematical Theory of Strong Emergence using Multiscale Variety (Bar-Yam, 2004a)

Author(s):

Yaneer Bar-Yam (yaneer@necsi.org)

New England Complex Systems Institute, 24 Mt. Auburn St., Cambridge, MA 02138, TEL 617-547-4100   FAX 617-661-7711

necsi@necsi.org

http://necsi.org/faculty/bar-yam.html

From the document:

We argue conceptually and then demonstrate mathematically that it is possible to define a scientifically meaningful notion of strong emergence. A strong emergent property is a property of the system that cannot be found in the properties of the system's parts or in the interactions between the parts. The possibility of strong emergence follows from an ensemble perspective, which states that physical systems are only meaningful as ensembles rather than individual states. Emergent properties reside in the properties of the ensemble rather than of any individual state. A simple example is the case of a string of bits including a parity bit, i.e. the bits are constrained to have, e.g., an odd number of ON bits. This constraint is a property of the entire system that cannot be identified through any set of observations of the state of any or all subsystems of the system. It is a property that can only be found in observations of the state of the system as a whole. A collective constraint is a property of the system, however, the constraint is caused when the environment interacts with the system to select the allowable states. Although selection in this context does not necessarily correspond to biological evolution, it does suggest that evolutionary processes may lead to such emergent properties. A mathematical characterization of multiscale variety captures the implications of strong emergent properties on all subsystems of the system. Strong emergent properties result in oscillations of multiscale variety with negative values, a distinctive property. Examples of relevant applications in the case of social systems include various allocation, optimization, and functional requirements on the behavior of a system. Strongly emergent properties imply a global to local causality that is conceptually disturbing (but allowed!) in the context of conventional science, and is important to how we think about biological and social systems.

Scientific document: Elements about the Emergence Issue – A Survey of Emergence Definitions (Deguet et al., 2005)

Author(s):

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Laurent Magnin

Université de Montréal, Canada

From the document:

Emergence, a concept that first appeared in philosophy, has been widely explored in the domain of complex systems and is sometimes considered to be the key ingredient that makes "complex systems" "complex". Our goal in this paper is to give a broad survey of emergence definitions, to extract a shared definition structure and to discuss some of the remaining issues. We do not know of any comparable surveys about the emergence concept. For this presentation, we start from a broadly applicable approach and finish with more specific propositions. We first present five selected works with a short analysis of each. We then propose a merged analysis in which we isolate a common structure through all definitions but also what we think needs further research. Finally, we briefly describe some perspectives about the emergence engine idea also referred to as emergent engineering. Keywords survey, emergence, complexity, levels definition.

Scientific document: Types and Forms of Emergence (Fromm, 2005a)

Author(s):

Jochen Fromm (fromm@vs.uni-kassel.de)

Distributed Systems Group, Kassel University, EECS Department for Electrical Engineering and Computer Science, Wilhelmshöher Allee 73, D-34121 Kassel, Germany

http://www.vs.uni-kassel.de/~fromm/

From the document:

The knowledge of the different types of emergence is essential if we want to understand and master complex systems in science and engineering, respectively. This paper specifies a universal taxonomy and comprehensive classification of the major types and forms of emergence in Multi-Agent Systems, from simple types of intentional and predictable emergence in machines to more complex forms of weak, multiple and strong emergence.

Comments from DRDC reviewer:

The author reviews past works on the subject and proposes a new way to classify the types and forms of emergence.

Scientific document: Ten Questions about Emergence (Fromm, 2005b)

Author(s):

Jochen Fromm (fromm@vs.uni-kassel.de)

Distributed Systems Group, Kassel University, EECS Department for Electrical Engineering and Computer Science, Wilhelmshöher Allee 73, D-34121 Kassel, Germany

http://www.vs.uni-kassel.de/~fromm/

From the document:

Self-Organization is of growing importance for large distributed computing systems. In these systems, a central control and manual management is exceedingly difficult or even impossible. Emergence is widely recognized as the core principle behind self-organization. Therefore the idea to use both principles to control and organize large-scale distributed systems is very attractive and not so far off. Yet there are many open questions about emergence and self-organization, ranging from a clear definition and scientific understanding to the possible applications in engineering and technology, including the limitations of both concepts. Self-organizing systems with emergent properties are highly desirable, but also very challenging. We pose ten central questions about emergence, give preliminary answers, and identify four basic limits of self-organization: a size limit, a place limit, a complexity limit and finally a combinatorial limit.

<u>Scientific document</u>: Defining and Detecting Emergence in Complex Networks (Boschetti et al., 2005a)

Author(s):

Fabio Boschetti (fabio.boschetti@csiro.au)

CSIRO Marine Research, Floreat, WA, Australia

Mikhail Prokopenko (mikhail.prokopenko@csiro.au)

CSIRO Information and Communication Technology Centre, North Ryde, NSW, Australia

Ian Macreadie (ian.macreadie@csiro.au)

CSIRO Health Sciences and Nutrition, Parkville, Victoria, Australia

Anne-Marie Grisogono (Anne-Marie.Grisogono@dsto.defence.gov.au)

Defence Science and Technology Organisation, Edinburgh, SA, Australia

From the document:

Emergence is seen as the most significant feature discriminating "complex" from "non complex" systems. Nevertheless, no standard definition of emergence is currently available in the literature. This lack of a shared view affects the development of tools to detect and model emergence for both scientific and engineering applications. Here we review some definitions of emergence with the aim to describe how they can be implemented in algorithms to detect and model emergence in sensor and communication networks.

<u>Scientific document</u>: Emergence Versus Self-Organisation: Different Concepts but Promising When Combined (De Wolf and Holvoet, 2005)

Author(s):

Tom De Wolf (Tom.DeWolf@cs.kuleuven.ac.be)

Tom Holvoet (Tom.Holvoet@cs.kuleuven.ac.be)

Department of Computer Science, Kuleuven, Celestijnenlaan 200A, 3001 Leuven, Belgium.

From the document:

A clear terminology is essential in every research discipline. In the context of ESOA, a lot of confusion exists about the meaning of the terms emergence and self-organisation. One of the sources of the confusion comes from the fact that a combination of both phenomena often occurs in dynamical systems. In this paper a historic overview of the use of each concept as well as a working definition, that is compatible with the historic and current meaning of the concepts, is given. Each definition is explained by supporting it with important characteristics found in the literature. We show that emergence and self-organisation each emphasise different properties of a system. Both phenomena can exist in isolation. The paper also outlines some examples of such systems and considers the combination of emergence and self-organisation as a promising approach in complex multi-agent systems.

Comments from DRDC reviewer:

Definitions of emergence and self-organization are given. The DRDC reviewer is not sure if both concepts should be studied in isolation as they are in this paper.

<u>**Book**</u>: Emergence: From Chaos to Order (Holland, 1998)

Author(s):

John H. Holland

From Amazon.com

"Emergence" is the notion that the whole is more than the sum of its parts. John Holland, a MacArthur Fellow known as the "father of genetic algorithms," says this seemingly simple notion will be at the heart of the development of machines that can think for themselves. And while he claims that he'd rather do science than write about it, this is his second scientific philosophy book intended to increase public understanding of difficult concepts (his first was Hidden Order: How Adaptation Builds Complexity). One of the questions that Holland says emergence theory can help answer is: can we build systems from which more comes out than was put in? Think of the food replicators in the imaginary future of Star Trek--with some basic chemical building blocks and simple rules, those machines can produce everything from Klingon delicacies to Earl Grey tea. If scientists can understand and apply the knowledge they gather from studying emergent systems, we may soon witness the development of artificial intelligence, nanotech, biological machines, and other creations heretofore confined to science fiction. Using games, molecules, maps, and scientific theories as examples, Holland outlines how emergence works, emphasizing the interrelationships of simple rules and parts in generating a complex whole. Because of the theoretical depth, this book probably won't appeal to the casual reader of popular science, but those interested in delving a little deeper into the future of science and engineering will be fascinated. Holland's writing, while sometimes self-consciously precise, is clear, and he links his theoretical arguments to examples in the real world whenever possible. Emergence offers insight

not just to scientific advancement, but across many areas of human endeavor--business, the arts, even the evolution of society and the generation of new ideas. --Therese Littleton

Comments from DRDC reviewer:

This book is another classical document in this field.

<u>Book</u>: Emergence: The Connected Lives of Ants, Brains, Cities, and Software (Johnson, 2002)

Author(s):

Steven Johnson

From Amazon.com

An individual ant, like an individual neuron, is just about as dumb as can be. Connect enough of them together properly, though, and you get spontaneous intelligence. Web pundit Steven Johnson explains what we know about this phenomenon with a rare lucidity in Emergence: The Connected Lives of Ants, Brains, Cities, and Software. Starting with the weird behavior of the semi-colonial organisms we call slime molds, Johnson details the development of increasingly complex and familiar behavior among simple components: cells, insects, and software developers all find their place in greater schemes. Most game players, alas, live on something close to day-trader time, at least when they're in the middle of a game--thinking more about their next move than their next meal, and usually blissfully oblivious to the ten- or twenty-year trajectory of software development. No one wants to play with a toy that's going to be fun after a few decades of tinkering--the toys have to be engaging now, or kids will find other toys. Johnson has a knack for explaining complicated and counterintuitive ideas cleverly without stealing the scene. Though we're far from fully understanding how complex behavior manifests from simple units and rules, our awareness that such emergence is possible is guiding research across disciplines. Readers unfamiliar with the sciences of complexity will find Emergence an excellent starting point, while those who were chaotic before it was cool will appreciate its updates and wider scope. --Rob Lightner --

<u>Book</u>: Social Emergence: Societies As Complex Systems (Sawyer, 2005)

Author(s):

Keith R. Sawyer

From Amazon.com

<u>Sociologists have long believed that psychology alone can't explain what happens when people work together in complex modern societies. In contrast, most psychologists and economists believe that we can explain much about social life with an accurate theory of how individuals make choices and act on them. R. Keith Sawyer argues, however, that societies are complex dynamical systems, and that the best way to resolve these debates is by developing the concept of emergence, paying attention to multiple levels of analysis--individuals, interactions, and groups--</u>

with a dynamic focus on how social group phenomena emerge from communication processes among individual members.

3.4.2 Self-Organization

Scientific document: Selected Self-Organization and the Semiotics of Evolutionary Systems (Rocha, 1998)

Author(s):

Luis Mateus Rocha (rocha@lanl.gov)

Los Alamos National Laboratory, MS B256, Los Alamos, NM 87545, USA.

From the document:

In this paper I sketch a rough taxonomy of self-organization which may be of relevance in the study of cognitive and biological systems. I frame the problem both in terms of the language of secondorder cybernetics as well as the language of current theories of self-organization and complexity. The goal of establishing such a taxonomy is to allow for a classification of different tools used both in Artificial Intelligence and Artificial Life, so that different aspects of cognitive and biological systems may be incorporated in more accurate models of such systems. In particular, I defend, on the one hand, that self-organization alone is not rich enough for our intended simulations, and on the other, that genetic selection in biology and symbolic representation in cognitive science alone leave out the very important (self-organizing) characteristics of particular embodiments of evolving and learning systems.

Scientific document: When Can we Call a System Self-organizing? (Gershenson and Heylighen , 2003)

Author(s):

Carlos Gershenson (cgershen@vub.ac.be)

Francis Heylighen (fheyligh@vub.ac.be)

Centrum Leo Apostel, Vrije Universiteit Brussel, Krijgskundestraat 33, Brussels, 1160, Belgium, http://www.vub.ac.be/CLEA

From the document:

We do not attempt to provide yet another definition of selforganization, but explore the conditions under which we can model a system as self-organizing. These involve the dynamics of entropy, and the purpose, aspects, and description level chosen by an observer. We show how, changing the level or "graining" of description, the same system can appear selforganizing or self-disorganizing. We discuss ontological issues we face when studying self-organizing systems, and

analyse when designing and controlling artificial self-organizing systems is useful. We conclude that self-organization is a way of observing systems, not an absolute class of systems.

Comments from DRDC reviewer:

The authors answer the following question: *which are the necessary conditions in order to call a system "self-organizing"?* They first examine the role of dynamics in self-organizing systems. Using a parameter called statistical entropy, they underline the importance three factors in the evaluation of self-organization: the level of observation, the person that make observation and the boundaries between systems' states. One important conclusion that can be drawn from this paper is that the way architectures are described and modelled will have impacts on how we will be able to perceive self-organization and emergence. They raise the important question: *If we can describe a system using different levels, aspects, or representations, which is the one we should choose?*. Their answer is: "*the level should be the one where the prediction of the behaviour of the system is easiest; in other words, where we need least information to make predictions.*

<u>Scientific document</u>: The Science of Self-organization and Adaptivity (Heylighen, 2003)

Author(s):

Francis Heylighen, Center "Leo Apostel", Free University of Brussels, Belgium.

From the document:

The theory of self-organization and adaptivity has grown out of a variety of disciplines, including thermodynamics, cybernetics and computer modelling. The present article reviews its most important concepts and principles. It starts with an intuitive overview, illustrated by the examples of magnetization and Bénard convection, and concludes with the basics of mathematical modelling. Self-organization can be defined as the spontaneous creation of a globally coherent pattern out of local interactions. Because of its distributed character, this organization tends to be robust, resisting perturbations. The dynamics of a self-organizing system is typically non-linear, because of circular or feedback relations between the components. Positive feedback leads to an explosive growth, which ends when all components have been absorbed into the new configuration, leaving the system in a stable, negative feedback state. Non-linear systems have in general several stable states, and this number tends to increase (bifurcate) as an increasing input of energy pushes the system farther from its thermodynamic equilibrium. To adapt to a changing environment, the system needs a variety of stable states that is large enough to react to all perturbations but not so large as to make its evolution uncontrollably chaotic. The most adequate states are selected according to their fitness, either directly by the environment, or by subsystems that have adapted to the environment at an earlier stage. Formally, the basic mechanism underlying self-organization is the (often noise-driven) variation which explores different regions in the system's state space until it enters an attractor. This precludes further variation outside the attractor, and thus restricts the freedom of the system's components to behave independently. This is equivalent to the increase of coherence, or decrease of statistical entropy, that defines selforganization.

Scientific document: Self-Organization in Distributed Systems Engineering -- Introduction to the Special Issue (Zambonelli and Rana, 2005)

Author(s):

Franco Zambonelli, Omer F. Rana

FAQ document: Self-Organizing Systems (SOS) FAQ, Frequently Asked Questions Version 2.98 June 2005 (can be found at CALRESCO, 2006)

Web site:

http://www.calresco.org/sos/sosfaq.htm

Scientific document: Self-Organizing Traffic Lights (Gershenson, 2005b)

Author(s):

Carlos Gershenson (cgershen@vub.ac.be)

Centrum Leo Apostel, Vrije Universiteit Brussel, Krijgskundestraat 33, Brussels, 1160, Belgium

http://www.vub.ac.be/CLEA

From the document:

Steering traffic in cities is a very complex task, since improving efficiency involves the coordination of many actors. Traditional approaches attempt to optimize traffic lights for a particular density and configuration of traffic. The disadvantage of this lies in the fact that traffic densities and configurations change constantly. Traffic seems to be an adaptation problem rather than an optimization problem. We propose a simple and feasible alternative, in which traffic lights self-organize to improve traffic flow. We use a multi-agent simulation to study three self-organizing methods, which are able to outperform traditional rigid and adaptive methods. Using simple rules and no direct communication, traffic lights are able to self-organize and adapt to changing traffic conditions, reducing waiting times, number of stopped cars, and increasing average speeds.

3.4.3 Self-adaptation

Scientific document: Self-Adaptation and Dynamic Environment Experiments with Evolvable Virtual Machines (Nowostawski et al., 2005)

Author(s):

Mariusz Nowostawski (mnowostawski@infoscience.otago.ac.nz)

Department Information Science, University of Otago, Dunedin, New Zealand

Lucien Epiney (lucien.epiney@epfl.ch)

Swiss Federal Institute of Technology, EPFL, Lausanne

Martin Purvis (mpurvis@infoscience.otago.ac.nz)

Department Information Science, University of Otago, Dunedin, New Zealand

From the document:

Increasing complexity of software applications forces researchers to look for automated ways of programming and adapting these systems. Self-adapting, self-organising software system is one of the possible ways to tackle and manage higher complexity. A set of small independent problem solvers, working together in a dynamic environment, solving multiple tasks, and dynamically adapting to changing requirements is one way of achieving true self-adaptation in software systems. Our work presents a dynamic multi-task environment and experiments with a self-adapting software system. The Evolvable Virtual Machine (EVM) architecture is a model for building complex hierarchically organised software systems. The intrinsic properties of EVM allow the independent programs to evolve into higher levels of complexity, in a way analogous to multi-level, or hierarchical evolutionary processes. The EVM is designed to evolve structures of self-maintaining, self-adapting ensembles, that are open-ended and hierarchically organised. This article discusses the EVM architecture together with different statistical exploration methods that can be used with it. Based on experimental results, certain behaviours that exhibit self-adaptation in the EVM system are discussed.

<u>Scientific document</u>: A Conflict Resolution Control Architecture for Self-Adaptive Software (Badr et al., 2002)

Author(s):

N. Badr (cmsnbadr@livjm.ac.uk)

D. Reilly (d.reilly@livjm.ac.uk)

A.TalebBendiab (A.Talebbendiab@livjm.ac.uk)

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From the document:

An essential feature of dependable software is its adaptive capability to respond to changes that occur in its operating environment through the dynamic transformation and reconfiguration of its components and/or services. Such adaptive capability is often a design aspect derived from the software architecture model, which describes the software components and their interactions, the properties and policies that regulate the composition of the components and norms that limit the allowable systems adaptation operations. Research in reflective middleware architectures and policybased distributed systems management has focused on the use of managerial or meta-level

protocols to attain reactive adaptive behaviour. However, reflective and policy-based management approaches alone cannot address all of the needs of self-adaptive software due to their inability to maintain a faithful runtime model of the system. This paper considers the development of control architecture for selfadaptive software, which combines conflict resolution and control strategies to resolve runtime conflicts. In particular, the paper describes a prototype service-based architecture, implemented using Java and Jini technologies, which provides runtime monitoring and conflict resolution to support software self-adaptation.

Scientific document: An Organization Centric Approach to Viewing Adaptation in Complex Adaptive Systems (Klyubin, 2002)

Author(s):

Alexander Klyubin

From the document:

In this thesis adaptation in Complex Adaptive Systems (CAS) is viewed as structural changes inside system resulting from system dynamics as well as its environment. Sufficiently complex systems tend to settle into different stable organizations in different environments. Successful adaptation is viewed as formation and persistence of stable organization inside system both with the help and despite environmental influences. This point of view is elaborated in more detail. Its implications concerning performance of systems and applications to designing adaptive systems are outlined as well. Primary implication is that in sufficiently complex systems stability of organization to recurrent perturbations increases. The claim has been verified by studying well-known adaptive systems, such as systems using evolutionary computation, ecosystems, neural networks, etc., as well as by experiments carried out on specially designed simple CAS. As systems are used for performing some function or computation, excessive increase in stability or decrease sensitivity to stimuli is an unwelcome effect degrading system performance. Accordingly, what is desired is designing systems or applying them so that their stable organization is also useful from functional point of view. Additionally we propose that coadaptation of system and its environment may be the necessary natural force which keeps system useful by preventing it from becoming to stable or unresponsive. Accordingly, we propose that in some systems tighter coadaptation might be used instead of specialized artificial techniques. The organization of thesis is as follows: first, background information concerning CAS is provided; next, the organization-centric view on successful adaptation as structural change towards increased stability of internal organization is elaborated in more detail; in second part design of a simple framework is discussed thoroughly, to be used later in the thesis for carrying out experiments in order to verify the claims stated earlier; finally, results of several experiments and future work directions are discussed.

Scientific document: Task-based Self-adaptation (Garlan et al., 2004)

Author(s):

David Garlan (garlan@cs.cmu.edu)

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From the document:

Recently there has been increasing interest in developing systems that can adapt dynamically to cope with changing environmental conditions and unexpected system errors. Most efforts for achieving self-adaptation have focused on the mechanisms for detecting opportunities for improvement and then taking appropriate action. However, such mechanisms beg the question: what is the system trying to achieve? In a given situation there may be many possible adaptations, and knowing which one to pick is a difficult question. In this paper we advocate the use of explicit representation of user task as a critical element in addressing this missing link.

<u>Scientific document</u>: Constraint-Guided Self-adaptation (Sandeep and Ledeczi, 2003)

Author(s):

Sandeep Neema (neemask@isis.vanderbilt.edu)

Akos Ledeczi (akos@isis.vanderbilt.edu)

Institute for Software Integrated Systems, Vanderbilt University, Nashville, TN 37235, USA

From the document:

We present an approach to self-adaptive systems utilizing explicit models of the design-space of the application. The design-space is captured by a hierarchical signal flow representation that allows the specification of alternatives for any component at any level in the model hierarchy. Non-functional requirements and additional knowledge about the system are captured by formal constraints parameterized by operational parameters, such as latency, accuracy, error rate, etc, that are measured at run-time. The constraints and the models are embedded in the running system forming the operation-space of the application. When changes in the monitored parameters trigger a reconfiguration, the operation space is explored utilizing a symbolic constraint satisfaction method relying on Ordered Binary Decision Diagrams. Once a new configuration that satisfies all the constraints is found the reconfiguration takes place.

<u>Scientific document</u>: Self Adaptive Software: A Position Paper (Laddaga and Robertson, 2004)

Author(s):

Robert Laddaga (rladdaga@ai.mit.edu)

MIT CSAIL

Paul Robertson (paulr@doll.com)

Dynamic Object Language Labs

From the document:

In this paper, we define Self Adaptive Software (SAS), discuss paradigms for implementing SAS, the core problem of self evaluation, discuss some applications, and indicate some area of future work.

Scientific document: Self-Adaptation in Next Generation Internet Networks: a Traffic Aware Approach (Sabella et al., 2005)

Author(s):

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3.4.4 Self-recovering, Self-repair

Scientific document: Evolvable Recovery Membranes in Self-monitoring Aerospace Vehicles (Wang and Prokopenko, 2004)

Author(s):

Peter Wang (fpeter.wang@csiro.au)

Mikhail Prokopenko (mikhail.prokopenkog@csiro.au)

Centre for Intelligent Systems Design, CSIRO Information and Communication Technologies Centre, Locked bag 17, North Ryde, NSW 1670, Australia

From the document:

In this paper we proposed and verified a methodology underlying the design of localised algorithms for complex multi-agent systems, exemplified by self-monitoring aerospace vehicles. In particular, we considered the emergence of selforganising impact boundaries and recovery

membranes, separating damaged and/or potentially recovering regions from less a affected agents. In order to identify phase transitions in system's dynamics, we investigated graph-theoretic and information-theoretic metrics, and incorporated them within fitness functions for a genetic algorithm. The GA involved a generation gap strategy and targeted a response time as well as spatial connectivity, temporal persistence and size of emergent boundaries and membranes. A variety of stable spatiotemporal patterns were produced under selection pressure, highlighting the potential for the design at the edge of chaos.

3.4.5 Self-replication

<u>Scientific document</u>: On Self-referential Shape Replication in Robust Aerospace Vehicles (Prokopenko and Wang, 2004a)

Author(s):

Peter Wang (fpeter.wang@csiro.au)

Mikhail Prokopenko (mikhail.prokopenkog@csiro.au)

Centre for Intelligent Systems Design, CSIRO Information and Communication Technologies Centre, Locked bag 17, North Ryde, NSW 1670, Australia

From the document:

We describe a multi-cellular shape replication mechanism implemented in a sensing and communication network, motivated by robust self-monitoring and self-repairing aerospace vehicles. In particular, we propose a self-referential representation (a .genome.), enabling self-inspection and selfrepair; an algorithm solving the problem for connected and disconnected shapes; and a robust algorithm recovering from possible errors in the .genome.. The presented mechanism can replicate combinations of prede_ned shapes and arbitrary shapes that self-organise in response to occurring damage.

<u>Scientific document</u>: The Firm as a Self-Reproducing System (Luksha, 2003)

Author(s):

Pavel O. Luksha (Pavel.luksha@mstal.ru)

The Higher School of Economics, Moscow

From the document:

Two generally accepted visions of a firm in economics, the classical (a firm as a profitmaximizing technology-bearer) and the neoclassical (a firm as a set of interdependent contracts to allocate resources) can be amended with a third one within an evolutionary paradigm: a firm is a survivor and thus a self-reproducer (and this looks as its 'supporting' property, but in fact it is its key function!). Application of von Neumann's model of universal self-reproducing automate allows to

point out that four key elements should exist in a self-reproducing firm: (1) technologies specific to the firm, (2) implementers transforming technologies into actions, (3) tutors, translating technologies to new (and existing) implementers, and (4) a coordinator to ensure consistency and synchronization of these processes. Self-reproduction of firm is one layer between self-reproduction of social individuals and that of a society. Certain properties of a formal dynamic model of firm self-reproduction are considered. There is a number of implications of firm's self-reproductive nature, on side of its internal and external factors, and evolution. It is also argued that historically, a transition towards 'self-reproductive' firm is already occurring (as this function is concisely understood), and it appears to be a part of firm natural evolution towards a more complex and more efficient social structure.

Comments from DRDC reviewer:

This paper describes firms as complex systems. The authors use the concept of Systems Thinking and Von Neumann's model to show survivability of firms through self-adaptation. Many important concepts should be re-used in a similar analysis for military complex systems.

<u>Scientific document</u>: A Macroscopic View of Self-Replication (Mange et al., 2004)

Author(s):

Daniel Mange, André Stauffer, Leonardo Peparolo, and Gianluca Tempesti.

From the document:

In 1953, Crick and Watson published their landmark paper revealing the detailed structure of theDNA double helix. Several years earlier, von Neumann embedded a very complex configuration, a universal interpreter–copier, into a cellular array. Astoundingly, the structure of this configuration, able to realize the self-replication of any computing machine, including a universal Turing machine, shares several common traits with the structure of living cells as defined by Crick and Watson's discovery. To commemorate the 100th anniversary of von Neumann's birth, this paper presents a macroscopic analysis of self-replication in computing machines using three examples. After describing self-replication in von Neumann's universal interpreter–copier, we will revisit the famous self-replicating loop designed by Langton in 1984. In order to overcome some of the major drawbacks of Langton's loop, namely, its lack of functionality and the fact that it is ill-adapted for a realization in electronic circuits, we present a novel self-replicating loop, the Tom Thumb loop. Endowed with the same capabilities as von Neumann's interpreter–copier, i.e., the possibility of replicating computing machines of any complexity, our loop is moreover specifically designed for the implementation of self-replicating structures in programmable digital logic.

3.4.6 Robustness

<u>Scientific document</u>: Optimization of Robustness and Connectivity on Complex Networks (Shargel et al., 2003)

Author(s):

Shargel B, Sayama H, Epstein IR, Bar-Yam Y.

New England Complex Systems Institute, 24 Mt. Auburn St., Cambridge, MA 02138, TEL 617-547-4100 FAX 617-661-7711

necsi@necsi.org

http://necsi.org/faculty/bar-yam.html

From the document:

Scale-free networks rely on a relatively small number of highly connected nodes to achieve a high degree of interconnectivity and robustness to random failure, but suffer from a high sensitivity to directed attack. In this paper we describe a parameterized family of networks and analyze their connectivity and sensitivity, identifying a network that has an interconnectedness closer to that of a scale-free network, a robustness to attack closer to that of an exponential network, and a resistance to failure better than that of either of those networks.

Scientific document: The Role of Redundancy in the Robustness of Random Boolean Networks (Gershenson et al., 2005)

Author(s):

Carlos Gershenson (cgershen@vub.ac.be)

Vrije Universiteit Brussel, Krijgskundestraat 33 B-1160 Brussel, Belgium

Stuart A. Kauffman (skauffman@ucalgary.ca)

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Ilya Shmulevich (is@ieee.org)

Institute for Systems Biology, 1441 North 34th Street, Seattle, WA, USA 98103-8904

From the document:

Evolution depends on the possibility of successfully exploring fitness landscapes via mutation and recombination. With these search procedures, exploration is difficult in "rugged" fitness landscapes, where small mutations can drastically change functionalities in an organism. Random Boolean networks (RBNs), being general models, can be used to explore theories of how evolution can take place in rugged landscapes; or even change the landscapes.

In this paper, we study the effect that redundant nodes have on the robustness of RBNs. Using computer simulations, we have found that the addition of redundant nodes to RBNs increases their robustness. We conjecture that redundancy is a way of "smoothening" fitness landscapes. Therefore, redundancy can facilitate evolutionary searches. However, too much redundancy could reduce the rate of adaptation of an evolutionary process. Our results also provide supporting evidence in favour of Kauffman's conjecture (Kauffman, 2000, p.195).

3.4.7 Performance

<u>Scientific document</u>: Evaluating Team Performance at the Edge of Chaos (Prokopenko and Wang, 2004b)

Author(s):

Mikhail Prokopenko (fmikhail.prokopenko@csiro.au)
Peter Wang (peter.wangg@csiro.au)

CSIRO Mathematical and Information Sciences, Locked Bag 17, North Ryde, NSW 1670, Australia.

From the document:

We introduce a concise approach to teamwork evaluation on multiple levels -- dealing with agent's behaviour spread and multi-agent coordination potential, and abstracting away the team decision process. The presented quantitative information-theoretic methods measure behavioural and epistemic entropy, and detect phase transitions -- the edge of chaos -- in team performance. The techniques clearly identify under-performing states, where a change in tactics may be warranted. This approach is a step towards a unified quantitative framework on behavioural and belief dynamics in complex multi-agent systems.

3.5 Metrics for Complex Adaptive Systems

<u>Scientific document</u>: Evaluating Complexity in Hierarchically Organized Systems (Araujo and Caraca, 1999)

Author(s):

T. Araujo (tanya@iseg.utl.pt)

J. Caraca

ISEG Technical University of Lisbon, UECE – Research Unit on Complexity in Economics

Comments from DRDC reviewer:

Interesting ideas are presented in this “hard to find” paper.

PhD thesis: Syntactic Measures of Complexity (Edmonds, 1999)

Author(s):

Bruce Edmonds (bruce@edmonds.name)

http://bruce.edmonds.name/

24 Mt. Auburn St., Cambridge, MA 02138, TEL 617-547-4100, FAX 617-661-7711.

From the document:

This thesis analyses the conception and measurement of complexity and then applies it to some aspects of formal languages. It starts with a review of the philosophy of modelling. It continues by considering some simple examples to establish intuitions about the common use of 'complexity' and goes on to examine what complexity can usefully be attributed to as a property. It argues that it most useful as an attribute of the specification of a model. Some unsatisfactory accounts of complexity are discussed as motivation for the definition of complexity that is then suggested. Some other accounts of complexity are shown to be special cases of the one suggested here. This approach is then applied to formal languages. A set of properties of analytic complexity are set-out. The set of measures which satisfy these properties is formally investigated. The cyclomatic number of a representation of expressions is put forward to model analytic complexity. In order to analyse shifts in complexity a formal device called syntactic structures is defined. This consists of layers of syntaxes, each with its own production rules which generate the contents of that layer. Each syntactic structure can use substitutions from lower such structures, so that collections of such structures can form hierarchies. These approaches to are then applied to axiomatic and proof theoretic aspects of logic. Some potential methods of simplification are suggested. Finally some remarks are made about the philosophical applications of this approach. The appendices include a survey of measures of complexity in the literature; a brief description of a software tool written to explore syntactic structures, two relevant papers on the application of these ideas to scientific modelling and economics, and an extensive bibliography.

Comments from DRDC reviewer:

This PhD thesis is often cited by other authors in the scientific literature. It brings many important elements to the study o complex systems. The author's goals are: *to lay bare assumptions and relativisations involved in the usage of the term "complexity"; to allow a meaningful comparison between different formulations of complexity across different fields of study; to lay the foundations for formalisations of complexity, in different circumstances; to aid the formulation of deeper insights into possible causes of complexity; and finally to allow the development of systematic approaches to simplification.* The author first defines the concepts surrounding model and modeling. He then defines the word "complexity" and gives many hints on how (and on what bases) complexity can be measured. Among other things, he gives a detailed list of some existing formulations of complexity. Many authors have re-used some parts of this list in their publications. Dr Edmonds also has a web page containing a bibliography of measures of complexity. It is located at this address:

http://bruce.edmonds.name/combib/.

<u>Scientific document</u>: Systems analysis: mathematical modeling and approach to structural complexity measure using polyhedral dynamics approach (Degtiarev, 2000)

Author(s):

Konstantin Y. Degtiarev, (konstantin.degtiarev@emu.edu.tr)

Eastern Mediterranean University (EMU), Computer Engineering Department, PO Box 95, via Mersin 10, TURKEY.

From the document:

This research paper analyzes and proposes modification of the Polyhedral Dynamics procedure which is based on algebraic (and geometric) representation of a system's structure as a simplicial complex. Mathematical analysis of complex refers to the studying of multidimensional chains of connectivity, and its results provide a background for measuring structural complexity. The term «complexity» is many-sided, and in the present paper it is examined through connectivity and relations between a system's elements. As it is discussed, complexity of structure expressed in numeric form is non-informative, but even at the initial stage of analysis it becomes reasonable to express complexity linguistically, to fill the results of the mathematical modeling stage with meaning. The appropriateness of a sequential using of mathematical and logical models is considered.

<u>Scientific document</u>: Complexity in Manufacturing: An Information Theoretic Approach (Calinescu et al., 2001)

Author(s):

Ani Calinescu (Ani.Calinescu@comlab.ox.ac.uk), J. Efstathiou, S. Sivadasan, J. Schirn and L. Huaccho Huatuco

Oxford University Computing Laboratory, Oxford Manufacturing Research Group based in the Engineering Science Department of Oxford University.

From the document:

We review information theoretic (entropic) measures of the expected amount of information needed to describe the state of manufacturing system and assess four measures according to our proposed criteria of generality, practicability and meaningfulness of results. We propose a measure of system complexity that takes account of the dynamic and structural aspects of a manufacturing system and briefly describe an operational method for measuring and comparing the complexity of manufacturing systems. The paper closes with a research agenda for the complexity of manufacturing systems.

<u>Scientific document</u>: Effective Complexity (Gell-Mann and Lloyd, 2003)

Author(s):

Murray Gell-Mann, Seth Lloyd

Santa Fe Institute, 1399 Hyde Park Road, Santa Fe, NM 87501

http://www.santafe.edu/

From the document:

It would take a great many different concepts - or quantities - to capture all of our notions of what is meant by complexity (or its opposite, simplicity.) However, the notion that corresponds most closely to what we mean by complexity in ordinary conversation and in most scientific discourse is "effective complexity." In nontechnical language, we can define the effective complexity (EC) of an entity as the length of a highly compressed description of its regularities [6,7,11]. For a more technical definition, we need a formal approach both to the notion of minimum description length and to the distinction between regularities and those features that are treated as random or incidental.

Scientific document: Characterizing Complex Product Architectures (Sharman and Yassine, 2004)

Author(s):

David M. Sharman (1) and Ali A. Yassine (2)

(1) Massachusetts Institute of Technology, Cambridge, MA 02139

(2) Department of General Engineering, University of Illinois at Urbana-Champaign, 117 Transportation Building, Urbana, IL 61801

From the document:

Due to the large-scale nature of complex product architectures, it is necessary to develop some form of abstraction in order to be able to describe and grasp the structure of the product, facilitating product modularization. In this paper we develop three methods for describing product architectures: (a) the Dependency Structure Matrix (DSM), (b) Molecular Diagrams (MD), and (c) Visibility-Dependency (VD) signature diagrams. Each method has its own language (and abstraction), which can be used to qualitatively or quantitatively characterize any given architecture spanning the modular-integrated continuum. A consequence of abstraction is the loss of some detail. So, it is important to choose the correct method (and resolution) to characterize the architecture in order to retain the salient details. The proposed methods are suited for describing architectures of varying levels of complexity and detail. The three methods are demonstrated using a sequence of illustrative simple examples and a case-study analysis of a complex product architecture for an industrial gas turbine.

Scientific document: Multiscale Complexity -- Entropy (Bar-Yam, 2004c)

Author(s):

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http://necsi.org/faculty/bar-yam.html

From the document:

We discuss the role of scale dependence of entropy/complexity and its relationship to component interdependence. The complexity as a function of scale of observation is expressed in terms of subsystem entropies for a system having a description in terms of variables that have the same a-priori scale. The sum of the complexity over all scales is the same for any system with the same number of underlying degrees of freedom (variables), even though the complexity at specific scales differs due to the organization / interdependence of these degrees of freedom. This reflects a tradeoff of complexity at different scales of observation. Calculation of this complexity for a simple frustrated system reveals that it is possible for the complexity to be negative. This is consistent with the possibility that observations of a system that include some errors may actually cause, on average, negative knowledge, i.e. incorrect expectations.

Web site: Software Metrics – A subdivided bibliography

Web site:

http://irb.cs.uni-magdeburg.de/sw-eng/us/bibliography/bib_main.shtml

Author(s):

Prof. Dr.-Ing. habil. Reiner R. Dumke

Lehrstuhl für Softwaretechnik, http://irb.cs.uni-magdeburg.de/~dumke/dumke.html

Comments from DRDC reviewer:

This web site presents a complete review of references on software metrics. Subjects include: Software Measurement, Measurement foundations, Derivation of Software Metrics, Software Process Improvement, Software Management, Software Quality, Properties of Software Metrics, Evaluation, Statistical Analysis, Metrics Validation, Standards, Measurement Frameworks/Programs, Experience Factories and Metrics Data Bases, Software Metrics, Overview, Requirement Analysis Metrics, Project/Requirement/Risk Management, Problem Definition Text Analysis, Requirement Analysis, Specification Metrics, Cost/Effort/Size estimation, COCOMO, Function/Object/Process Points, Formal Specification, Design Metrics, Software Systems/ Architecture, Modularization Measurement, Components/Integration Measures, Software Agents Measurement, Web (Service) Measurement, Pseudocode Measures, Communication/Interaction Measures, Object Oriented Design Measures, Review/Inspection/Audits Measures, Information Measures, Code Metrics, Halsteads Software

Science, McCabes Cyclomatic Number, Source Code Measures, Formal Analysis and Grammars, Control Flow Measures, Data (Flow) Measures, Hybrid Measures, Concurrency Measurement, Object Oriented Programming, Functional Programming, Logical Programming, Visual Programming, Test Metrics, Test Coverage/ OO Testing, Reliability Measurement, Security Measurement, Performance Measurement, Maintenance Metrics, Modifiability/Portability Measures, Reusability/COTS Measures, Programmers Productivity Measures, Evaluation/Certification Measures, Measurement Tools, Program Analysis, Metric Analysis, Process Analysis and Management, Software Quality Assurance.

3.6 Sources of Complexity

Scientific document: Sources of Complexity (Burgess and Maiese, 2004)

Author(s):

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Alex Ryan (alex.ryan@dsto.defence.gov.au)

Land Operations Division, Defence Science and Technology Organisation, PO Box 1500 Edinburgh SA 5111.

From the document:

Many intractable conflicts are extremely complex processes with large numbers of actors using many different strategies to pursue many different objectives over a long period of time. The ability of people to deal constructively with these conflicts is largely determined by how well they understand the situation. If the parties do not understand who is involved, what they are doing, and why, it is very easy for them to adopt strategies that are unlikely to succeed.

Comments from DRDC reviewer:

This paper presents a short overview on how to deal with complex conflicts between people and between organizations. Some elements of solution are presented.

3.7 Perception and Comprehension of Complexity

Scientific document: Cognitive Readiness in Network-Centric Operations (Wesensten et al., 2005)

Author(s):

Nancy J. Wesensten, Gregory Belenky and Thomas J. Balkin.

Scientific document: Understanding environmental and geographical complexities through similarity matching (Holt, 2000)

Author(s):

Holt, A. (aholt@infoscience.otago.ac.nz)

Department of Information Science, University of Otago, PO Box 56, Dunedin New Zealand.

From the document:

This article illustrates similarity-matching techniques applied to environmental and geographical information domains. The general concept outlined is that similarity is a generative technique to analyse the cached information inherent in physical and social sciences. In essence, similarity is utilised to group natural kinds that manifest similar amenities in complex environments.

Scientific document: A Cognitive Interpretation of Organizational Complexity (Fioretti and Visser, 2004)

Author(s):

Guido Fioretti and Bauke Visser

From the document:

Organizational theory has construed complexity as an objective characteristic of either the structure or the behavior of an organization. We argue that, in order to further our understanding, complexity should be understood in terms of the human cognition of a structure or behavior. This cognitive twist is illustrated by means of two theoretical approaches, whose relationship is discussed.

3.8 Managing Complexity and Complex Adaptive Systems

Scientific document: Managing Complexity (Chassinet al., 2004)

Author(s):

David P. CHASSIN

Energy Science and Technology Division, Pacific Northwest National Laboratory, Richland, Washington 99352

Christian POSSE and Joel MALARD

Fundamental Sciences Division, Pacific Northwest National Laboratory, Richland, Washington 99352

From the document:

Physical analogs have shown considerable promise for understanding the behavior of complex adaptive systems, including macroeconomics, biological systems, social networks, and electric

power markets. Many of today's most challenging technical and policy questions can be reduced to a distributed economic control problem. Indeed, economically-based control of large-scale systems is founded on the conjecture that the price-based regulation (e.g., auctions, markets) results in an optimal allocation of resources and emergent optimal system control. This paper explores the state of the art in the use physical analogs for understanding the behavior of some econophysical systems and deriving stable and robust control strategies for them. In particular we review and discuss applications of some analytic methods based on a thermodynamic metaphor according to which the interplay between system entropy and conservation laws gives rise to intuitive and governing global properties of complex systems that cannot be otherwise understood.

3.9 Connectivity and Communication in Complex Adaptive Systems

Scientific document: Complexity and Connectivity in Ecosystems (Klomp and Green, 1996)

Author(s):

Nicholas I. Klomp and David G. Green.

From the document:

Ecosystems are complex. The number of species and the variety of interactions among biotic and abiotic factors are too great to be adequately explained by traditional ecological concepts. The use of computer-generated models to simulate environmental events can provide a greater understanding of complexity in ecosystems, and offers better predictive powers to conservation and land managers. Ecosystem connectivity is just one area of complex ecological problems that has been tackled by computer modelling with considerable success. With a better understanding of connectivity in fragmented landscapes, land managers will be better equipped to slow the loss of crucial habitats and the rate of species extinctions. The role of computer-generated models in understanding ecological complexity is likely to become more commonplace in the future, particularly given the increasingly urgent need to manage the world's ever decreasing natural heritage.

Scientific document: Communnication and Coordination (Miller and Moser, 2003)

Author(s):

John Miller (miller@santafe.edu)

Scott Moser

From the document:

Remarkable levels of coordination are observed among social agents; yet the exact mechanisms by which such agents coordinate are not well understood. Here we examine the role of

communication in achieving coordination|in particular, does endowing agents with the ability to communicate lead to more favorable outcomes? To pursue this question we employ an adaptive model of strategically communicating agents (Miller et al. [7]) playing the Stag Hunt game. We _nd that communication plays a key role in the ability of agents to reach and maintain superior coordination. In the absence of communication, agents tend to get trapped at the inferior coordination point. However, once agents reach a particular strategic threshold, sending even a priori meaningless messages serves to increase the likelihood that the population will coordinate on the superior outcome. While the system spends the majority of its time with well-coordinated behavior, it is not static|such periods are often punctuated by brief transitions in which the system switches to the alternative coordination point. We analyze the various mechanisms that account for this dynamic behavior and _nd that there are a few critical pathways by which the system transitions from one coordination point to another. Communication plays a critical, yet short-lived, role in one key pathway. Our analysis suggests that giving agents the ability to communicate even a priori meaningless messages may promote the emergence of a rich, and often robust, \ecology" of behaviors that allows agents to achieve new, and in this case superior, outcomes.

3.10 Aspects of Complexity and Chaos in Various Fields or Domains

3.10.1 Agent

<u>Scientific document</u>: An Analysis of Stochastic Game Theory for Multiagent Reinforcement Learning (Bowling and Veloso, 2000)

Author(s):

Michael Bowling abd Manuela Veloso

School of Computer Science, Carnegie Mellon University, Pittsburgh, PA 15213, USA

From the document:

Learning behaviors in a multiagent environment is crucial for developing and adapting multiagent systems. Reinforcement learning techniques have addressed this problem for a single agent acting in a stationary environment, which is modeled as a Markov decision process (MDP). But, multiagent environments are inherently non-stationary since the other agents are free to change their behavior as they also learn and adapt. Stochastic games, first studied in the game theory community, are a natural extension of MDPs to include multiple agents. In this paper we contribute a comprehensive presentation of the relevant techniques for solving stochastic games from both the game theory community and reinforcement learning communities. We examine the assumptions and limitations of these algorithms, and identify similarities between these algorithms, single agent reinforcement learners, and basic game theory techniques.

<u>Scientific document</u>: Agent-Oriented Software Engineering (Jenning and Wooldridge, 2001)

Author(s):

Nicholas R. Jennings (N.R.Jennings@qmw.ac.uk)

Michael Wooldridge (M.J.Wooldridge@qmw.ac.uk)

Department of Electronic Engineering, Queen Mary & Westfield College, University of London, London E1 4NS, United Kingdom

From the document:

Agent-oriented techniques represent an exciting new means of analysing, designing and building complex software systems. They have the potential to significantly improve current practice in software engineering and to extend the range of applications that can feasibly be tackled. Yet, to date, there have been few serious attempts to cast agent systems as a software engineering paradigm. This paper seeks to rectify this omission. Specifically, it will be argued that: (i) the conceptual apparatus of agent-oriented systems is well-suited to building software solutions for complex systems and (ii) agent-oriented approaches represent a genuine advance over the current state of the art for engineering complex systems. Following on from this view, the major issues raised by adopting an agent-oriented approach to software engineering are highlighted and discussed.

Scientific document: Agent-Based Modelling and the Environmental Complexity Thesis (Seth, 2002)

Author(s):

Anil K Seth (seth@nsi.edu)
The Neurosciences Institute, 10640 John Jay Hopkins Drive, San Diego, CA 92121, USA

From the document:

A variation of Godfrey-Smith's 'environmental complexity thesis' is described which draws together two broad themes; the relation of functional properties of behaviour to environmental structure, and the distinction between behavioural and mechanistic levels of description. The specific idea defended here is that behavioural and/or mechanistic complexity can be understood in terms of mediating well-adapted responses to environmental variability. Particular attention is paid to the value of agent-based modelling within this framework.

Scientific document: Intelligent Agents for Coalition Search and Rescue Task Support (Tate et al., 2004)

Author(s):

Austin Tate (a.tate@ed.ac.uk), Jeff Dalton (j.dalton@ed.ac.uk), Clauirton de Siebra (c.siebra@ed.ac.uk), Stuart Aitken (s.aitken@ed.ac.uk)

Artificial Intelligence Applications Institute (AIAI), University of Edinburgh, Edinburgh EH8 9LE, UK

Jeffrey M. Bradshaw (auszok@ihmc.us), Andrzej Uszok (jbradshaw@ihmc.us)

Institute for Human and Machine Cognition (IHMC), 40 S. Alcaniz, Pensacola, FL 32501, USA

Web site:

http://www.aiai.ed.ac.uk/project/cosar-ts/demo/isd/

From the document:

The Coalition Search and Rescue Task Support demonstration shows cooperative agents supporting a highly dynamic mission in which AI task planning, inter-agent collaboration, workflow enactment, policy-managed communications, semantic web queries, semantic web services matchmaking and knowledge-based notifications are employed.

3.10.2 Air Traffic Management

Scientific document: Modeling Distributed Human Decision-Making in Traffic Flow Management Operations (Campbell et al., 2000)

Author(s):

Keith C. Campbell (keithc@mitre.org)

Wayne W. Cooper (wcooper@mitre.org)

Daniel Greenbaum (dpg@mitre.org)

Leonard A. Wojcik (lwojcik@mitre.org)

Center for Advanced Aviation System Development, The MITRE Corporation, McLean, VA, US.

From the document:

This paper describes results from state-of-the-art computer simulation model of distributed human decision-making in Traffic Flow Management (TFM) operations when weather disrupts airline schedules. The computer model, called Intelligent agent-based Model for Policy Analysis of Collaborative TFM (IMPACT), is believed to be the world's first model to capture the behavioural complexity of human decision-making in TFM operations.

Scientific document: Complexity in air traffic control towers: A field study (Koros et al., 2003)

Author(s):

Anton Koros, Pamela S. Della Rocco, Gulshan Panjwani, Victor Ingurgio, Jean-François D'Arcy

Federal Aviation Administration, NAS Human Factors Group, William J. Hughes Technical Center, Building 28 Atlantic City International Airport, NJ 08405

From the document:

This study investigated factors that contribute to complexity and their incidence within Federal Aviation Administration Air Traffic Control Towers (ATCTs). Human Factors Specialists from the William J. Hughes Technical Center selected six sites representing a combination of high traffic volume, traffic mix, and/or converging runways. Sixty-two Air Traffic Control Specialists (ATCSs) from the six ATCTs rated 29 complexity factors from local and ground controller perspective. The relative contribution of each of the complexity factors was site- and position-specific. High traffic volume, frequency congestion, and runway/taxiway configuration were among the leading complexity factors at all sites and for both control positions. This study characterized the differences between facilities in terms of the key factors and their incidence and summarized the interview data describing the nature of the complexity. An enhanced understanding of ATCSs' decision making and tower complexity factors will help researchers predict the impact of automation and emerging technologies on controllers and ensure the continued safety and efficiency of the National Airspace System.

See also:

Mogford et al (1995)

Laudeman et al (1998)

3.10.3 Biology

Scientific document: Complexity and Fragility in Ecological Networks (Solé and Montoya, 2000)

Author(s):

Ricard V. Solé and José M. Montoya.

From the document:

A detailed analysis of three species-rich ecosystem food webs has shown that they display scale-free distributions of connections. Such graphs of interaction are in fact shared by a number of biological and technological networks, which have been shown to display a very high homeostasis against random removals of nodes. Here we analyse the response of these ecological graphs to both random and selective perturbations (directed to most connected species). Our results suggest that ecological networks are extremely robust against random removal but very fragile when selective attacks are used. These observations can have important consequences for biodiversity dynamics and conservation issues, current estimations of extinction rates and the relevance and definition of keystone species.

Scientific document: Robust time delay estimation of bioelectric signals using least absolute deviation neural network (Zhishun et al., 2005)

Author(s):

Zhishun Wang, He Zhenya and J.D.Z. Chen.

3.10.4 Cognition

<u>Scientific document</u>: The Impact of Structure on Cognitive Complexity in Air Traffic Control (Histon and Hansman, 2002)

Author(s):

Jonathan M. Histon and R. John Hansman

MIT International Center for Air Transportation, Department of Aeronautics & Astronautics, Massachusetts Institute of Technology, Cambridge, MA 02139, USA.

From the document:

Focused interviews with air traffic controllers and traffic management unit personnel, as well as analysis of traffic flow patterns based on Enhanced Traffic Management System (ETMS) data, suggest that controllers rely on underlying airspace structure to reduce the cognitive complexity of managing an air traffic control situation. To understand how structural elements reduce cognitive complexity, a framework has been developed relating structure, situation awareness, and a controller's working mental model. It is hypothesized that structure forms the basis for abstractions which simplify a controller's working mental model. The working mental model is used to support the key tasks of a controller identified by Pawlak (1996): planning, implementing, monitoring, and evaluating. Three examples of structure-based abstractions have been identified: standard flows, groupings, and critical points.

<u>Scientific document</u>: Complexity Mitigation Through Airspace Structure (Cummings et al., 2005)

Author(s):

M.L. Cummings, C.G. Tsonis

Massachusetts Institute of Technology, Cambridge, MA,

D.C. Cunha

Instituto Tecnológico de Aeronáutica, São José dos Campos, SP, Brazil

From the document:

Cognitive complexity is a term that appears frequently in air traffic control research literature, yet there has not been a significant distinction between different components of complexity, such as environmental, organizational, and display complexity, all which influence cognitive complexity. It is not well understood if and how these different sources of complexity add to

controller cognitive complexity and workload. In order to address this need for complexity decomposition and deconstruction, an experiment was conducted to explore whether or not different components of complexity could be effectively measured and compared. The goal of the experiment was to quantify whether or not structure in airspace sector design, in combination with changes in the external airspace environment, added to or mitigated perceived complexity measured through performance. The results demonstrate that for a representative ATC task, the dynamic environment complexity source was a significant contributor to performance, causing lower performance scores. There was no apparent effect, either positive or negative, from increasing airspace structure represented through a display.

3.10.5 Emergent Computing

See also Annex E for a suggested list of papers from ERCIM (2006).

Book: The Wisdom of Crowds (Surowiecki, 2005)

Author(s):

James Surowiecki

From Amazon.com

While our culture generally trusts experts and distrusts the wisdom of the masses, New Yorker business columnist Surowiecki argues that "under the right circumstances, groups are remarkably intelligent, and are often smarter than the smartest people in them." To support this almost counterintuitive proposition, Surowiecki explores problems involving cognition (we're all trying to identify a correct answer), coordination (we need to synchronize our individual activities with others) and cooperation (we have to act together despite our self-interest). His rubric, then, covers a range of problems, including driving in traffic, competing on TV game shows, maximizing stock market performance, voting for political candidates, navigating busy sidewalks, tracking SARS and designing Internet search engines like Google. If four basic conditions are met, a crowd's "collective intelligence" will produce better outcomes than a small group of experts, Surowiecki says, even if members of the crowd don't know all the facts or choose, individually, to act irrationally. "Wise crowds" need (1) diversity of opinion; (2) independence of members from one another; (3) decentralization; and (4) a good method for aggregating opinions. The diversity brings in different information; independence keeps people from being swayed by a single opinion leader; people's errors balance each other out; and including all opinions guarantees that the results are "smarter" than if a single expert had been in charge. Surowiecki's style is pleasantly informal, a tactical disguise for what might otherwise be rather dense material. He offers a great introduction to applied behavioral economics and game theory.

3.10.6 Human Factors: Perception, Comprehension, Communication and Collaboration

Scientific document: Issues in defining human roles and interactions in systems (Newman, 1999)

Author(s):

Richard A. Newman

Federal Data Corporation, Science and Engineering Group, 500 Scarborough Drive, Suite 205, Egg Harbor Township, NJ 08234.

From document:

This article describes the concept of human roles as an organizing principle for defining human interaction with a system. It also describes the six different roles humans can perform in terms of the Systems Engineering (SE) aspects of Human/System Integration (HSI). Four of these roles are associated with system performance and two roles are related to the development process. These two roles suggest that SE principles and practices be applied to the SE and system development processes as well as the system being developed. This paper provides a set of definitions for basic HSI concepts and for the six roles. It also discusses how people in these roles interact with the system and system environment and some of the HSI problems commonly encountered. The paper explains how use of roles as an organizing principal can aid in resolving these issues. These roles and interactions are relevant to large and small systems and all system environments.

Scientific document: Processes and Organizations as Systems: When the Processors Are People, Not Pentium (Pajerek , 2000)

Author(s):

Lorraine Pajerek

Lockheed Martin Federal Systems, 1801 State Route 17c, MD 0902, Owego, NY 13827.

From document:

The field of Human Factors in systems engineering is understood to comprise a wide range of issues from the physiology of workstation design to the psychology of job satisfaction. The study of the human role in systems takes on additional dimensions when the "system" in question is actually the process of developing products or systems and the organization performing the development process. This article discusses key differences pertaining to the human element in development processes versus traditional systems, and explores the impacts of its characteristics and behavior. Implications for work currently being done in the areas of process maturity and continuous process improvement are also presented.

Scientific document: Supporting Human Communication in Network-Based Systems Engineering (Harris, 2001)

Author(s):

David Harris (david.harris@unisa.edu.au)

Systems Engineering and Evaluation Centre, University of South Australia. The Levels Campus, Adelaide, SA 5095 AUSTRALIA

From the document:

The increased globalisation of Systems Engineering is spawning a range of activities in the support of systems engineering teams who are geographically dispersed. The primary focus is on ways in which these team members can exchange information easily, quickly and accurately. This paper takes the view that a network agent in a systems engineering design team comprises a computer plus a person, the two combining to form the intelligent network agent. A great deal of current activity is being put into the communication of data between computers. Relatively little is being put into supporting the communication between the people who are the most significant component of the "intelligent agent". This paper investigates the fundamental reasons why the communication is taking place and concludes that its purpose is to transfer from one agent to another sufficient information for the receiving agent to, eventually, supply a satisfactory deliverable to the sending agent. This implies the transfer, in some form, of a set of requirements. In such a transfer, these requirements will always be interface requirements. The paper goes on to discuss the transfer of computer-based data between dissimilar tools and the issues involved in this transfer. It then compares the domains of "expertise" of the tool and of the human user, and discusses the mutually supportive operation of these together. From this discussion, the paper proposes a firstcut set of requirements for the data exchange mechanism and its supporting environment.

Scientific document: A Framework for the Study of Individual Behavior and Social Interactions (Durlauf, 2001)

Author(s):

S. N. Durlauf

From the document:

Recent work in economics has begun to integrate sociological ideas onto the modelling of individual behavior. In particular, this new approach emphasizes how social context and social interdependences influence the ways in which individuals make choices. This paper provides an overview of an approach to integrating theoretical and empirical analysis of such environments. The analysis is based on a framework due to Brock and Durlauf (2000a, 2000b). Empirical evidence on behalf of this perspective is assessed and some policy implications are explored.

Scientific document: Human-agent Collaboration: Ontology and Framework for Designing Adaptive Human-agent Collaborative Architectures (Madni and Madni, 2002)

Author(s):

A.M. Madni, W. Lin. C. Madni

Intelligent Systems Technology, Inc.

<u>Scientific document</u>: Architecting Systems for Human Space Flight (Wocken and Dagli, 2002)

Author(s):

Wocken, G.F. (Gerald.f.wocken@boeing.com)

C.H. Dagli

Boing Space Communications, P.O. Box 240002, MC JB-10, Huntsville, AL, 35824-6402

<u>Scientific document</u>: Application of color to reduce complexity in air traffic control (Yuditsky et al., 2002)

Author(s):

Tanya Yuditsky, Randy L. Sollenberger, Pamela S. Della Rocco, Ferne Friedman-Berg, Carol A. Manning

Federal Aviation Administration, NAS Human Factors Group, William J. Hughes Technical Center, Building 28 Atlantic City International Airport, NJ 08405

From the document:

The United States Air Traffic Control (ATC) system is designed to provide for the safe and efficient flow of air traffic from origin to destination. The Federal Aviation Administration predicts that traffic levels will continue increasing over the foreseeable future. It is important to identify and reduce the factors that increase ATC complexity because of the potential consequences of errors. This research examined the application of specific information coding techniques to ATC displays as a method of reducing complexity in the en route environment. It tested color coding of (a) aircraft destination airport, (b) overflights, and (c) Special Use Airspace. Eight Certified Professional Controllers participated in the high fidelity, human-in-the-loop simulation. Results indicated that these specific enhancements may improve controller performance and efficiency. However, when we presented all of the enhancements simultaneously, we did not find the beneficial effects that occurred when we tested the enhancements individually. Further research is needed to systematically investigate the application of color to radar displays in the dynamic Air Traffic environment.

<u>Book</u>: The Logic of Failure, Recognizing and Avoiding Error in Complex Situations (Dörner , 1996)

Author(s):

Dietrich Dörner

From Amazon.com:

Identifies the roots of catastrophe, the small perfectly sensible steps that set the stage for disaster. In incisive analysis of real-life situations and hilarious computer simulations, the author helps those involved in strategic planning recognize and avoid such devastating errors.

Comments from http://photonplaza.blogspot.com:

The comments from Amazon are clearly incomplete. Doerner, a professor of Psychology at the University of Bamberg (Germany) uses empirical methods to study human decision-making processes, with an emphasis on understanding the ways in which these processes can go wrong. His work should be read by anyone with a responsibility for making decisions, particularly complex and important decisions. Doerner's basic tool for study is the simulation model. Many of his models bear a resemblence to Sim City and similar games, but are purpose-designed to shed light on particular questions. The nature of many of these models implies that they use human umpires, as well as computer processing. (Doerner uses the simulation results of other researchers, as well as his own experimental work, in developing the ideas in this book.)

One very interesting angle explored by Doerner is the danger, in decision-making tasks, of knowing too much--of becoming lost in detail and of always needing one more piece of information before coming to a decision. He posits that this problem "probably explains why organizations tend to institutionalize the separation of their information-gathering and decision-making branchs"--as in the development of staff organizations in the military. One cautionary note: the numbers of subjects used in the experiments cited tend to be fairly small, and no statistical significance tests are presented--thus, Doerner's conclusions about decision-making should be taken as suggestive rather than definitive. (The book was originally published in 1989: Prof Doerner has probably done considerable additional work since this time). Nevertheless, this book is a remarkable contribution to the study of decision-making, and contains a great number of thoughts worthy of serious consideration--both by those who study the field, and by practical decision makers themselves.

Comments from DRDC reviewer:

This is a psychologist view of how human perceive and understand complex systems. The author shows how the misunderstanding of these systems by human quickly lead to chaos. This is a very interesting book.

3.10.7 Mathematics

Scientific document: A Theory of Complexity for Continuous Time Systems (Ben-Hur et al., 2002)

Author(s):

Asa Ben-Hur

Biowulf Technologies, 2030 Addison, Suite 102, Berkeley, CA 94704 and Faculty of Industrial Engineering and Management, Technion, Haifa 32000, Israel

Hava T. Siegelmann

Laboratory for Information and Decision Systems, Massachusetts Institute of Technology, 77 Massachusetts Avenue, Cambridge, Massachusetts

Shmuel Fishman

Department of Physics, Technion, Haifa 32000, Israel

From the document:

We present a model of computation with ordinary differential equations (ODEs) which converge to attractors that are interpreted as the output of a computation. We introduce a measure of complexity for exponentially convergent ODEs, enabling an algorithmic analysis of continuous time flows and their comparison with discrete algorithms. We define polynomial and logarithmic continuous time complexity classes and show that an ODE which solves the maximum network flow problem has polynomial time complexity. We also analyze a simple flow that solves the Maximum problem in logarithmic time. We conjecture that a subclass of the continuous P is equivalent to the classical P.

3.10.8 Military Acquisition

Scientific document: Chaos Theory as a Model for Strategy Development (Bechtold, 1997)

Author(s):

Bechtold B.L.

From the document:

Uses chaos theory as a model and explores the requirements for strategizing in a rapidly-changing business environment. Conjectures that organizations in a fast-paced business environment need continuous processes of strategy development to be strategic. Suggests that strategic thinking needs to be embedded in the manager's role, all organizational processes, and the culture inself in order for an organization to be strategic.

Scientific document: The Real Requirement for Future Complex Military Systems – More than Just the Operational Need? (Rabbets et al., 2001)

Author(s):

Tim Rabbets, Simon Emerton and Steven Bradley.

From the document:

This paper shows how the real requirement for complex systems is not only driven by the operational need but also by the implementation technology and even by elements of the engineering process.

Scientific document: Large Scale Engineering and Evolutionary Change: Useful Concepts for Implementation of FORCEnet (Bar-Yam, 2002b)

Author(s):

Yaneer Bar-Yam

New England Complex Systems Institute, 24 Mt. Auburn St., Cambridge, MA 02138, TEL 617-547-4100 FAX 617-661-7711

necsi@necsi.org

http://necsi.org/faculty/bar-yam.html

Scientific document: Some Thoughts on Practical Approaches for Complex Systems (Ryan, 2003)

Author(s):

Michael Ryan

School of Information Technology and Electrical Engineering, The University of New South Wales, Australian Defence Force Academy, Northcott Drive, CANBERRA ACT 2600.

From the document:

The theme of this conference, "Practical Approaches for Complex Systems", is particularly appropriate because the adjectives focus directly on the two major challenges we face in systems engineering. First, the world is inherently complex [1] and complex problems do not generally have simple solutions. Yet, we cannot specify, develop, manage and operate complex systems by using processes that are complex beyond our overall capacity to understand and manage and where the component parts challenge our intuition [2]. Such complex processes can not, and do not stand the test of time. Our challenge is therefore to be able to find practical approaches to cope with complexity throughout the whole system life cycle. As an aside, this difficulty is not confined to systems engineering, its manifestations are readily obvious in almost any field of endeavour, especially those of project management, business, and public policy. Now, fortunately, we are standing on shoulders here—the discipline of systems engineering has come a long way and we already know a great deal about processes for managing complexity. By way of example, I would like to refer briefly to just two elements o f SE: first to illustrate that systems engineering already has strong practical approaches to solving complex problems; and second, to provide us with common ground to discuss further some practical implementation issues.

Scientific document: Designing Complex Adaptive Systems for Defence (Grisogono and Ryan, 2003)

Author(s):

Anne-Marie Grisogono (anne-marie.grisogono@dsto.defence.goc.au)

Alex Ryan (alex.ryan@dsto.defence.gov.au)

Land Operations Division, Defence Science and Technology Organisation, PO Box 1500 Edinburgh SA 5111.

From the document:

The complexity of defence systems has grown rapidly in recent years and has arguably already reached a level that challenges our human ability to understand, manage and steer the resulting highly interdependent and nonlinear defence enterprise. The next generation of defence systems must be more adaptive and agile, and must incorporate sufficient intelligence into their design to reduce the demands on human management. We can learn something about how to do this by examining naturally arising complex adaptive systems, and hence drawing insights into the research challenges defence has to address to bridge the gap between current system design practice and the evolution of future truly adaptive complex defence systems.

Comments from DRDC reviewer:

The author identifies some hints to make Complex Adaptive Systems (CAS) more adaptive. The authors support the fact that inherent complexity of large organizations can be effectively harnessed by addressing three key concepts: variation, interaction and selection (Ilachinski, 1996)). They base their study on the seven basics of CAS (Axelrod and Cohen, 2001): aggregation, building blocks, diversity, nonlinearity, tagging, flows and internal models.

Scientific document: Net-centric Warfare and its Impact on System-of-Systems (Zenishek and Usechak, 2005)

Author(s):

Lt Col Steven G. Zenishek, USAF and Dr. David Usechak

From the document:

The effects of Net-Centric Warfare (NCW) and its impact on the acquisition of System-of-Systems constructs as experienced by the acquisition of the Air Force Distributed Common Ground System Block 10.2 are examined. Block 10.2 is an Acquisition Category III program that is fielding a net-centric, service-oriented architecture for intelligence, surveillance, and reconnaissance. The NCW links sensors, communications systems, and weapons systems in an interconnected grid creating seamless data and information flows to warfighters, policy makers, and support personnel. The Office of the Assistant Secretary of Defense Networks and Information Integration has identified net-centric best practices as using a Service-oriented Architecture, implementing a datacentric strategy, information assurance strategy and use of Net-Centric Operations Warfare Reference Model. Block 10.2 has found these best practices shift the acquisition strategy from acquiring a System-of-Systems to acquiring an enterprise of services..

Comments from DRDC reviewer:

This article is lessons learned covering system-of-systems implementation processes. The authors describe the implementation of the Air Force Distributed Common Ground System Block 10.2 and its implications.

3.10.9 Military Operations

<u>Scientific document</u>: Complexity in C3I Systems (Cooper, 1994)

Author(s):

Clive Cooper (clivec@cs.adfa.edu.au)

Department of Computer Science, University College, Australian Defence Force Academy, Canberra A.C.T. 2600, Australia.

From the document:

Military systems depend on command, control, communications and intelligence (C3I). Modern systems are made exceedingly complex by the many human and technological elements involved. The sources of the complexity include dimensional complexity (processes and interactions on many levels), uncertainty and computational complexity. Methods of coping include use of AI and context-sensitive filters. Complexity provides a unifying concept for gaining a better insight into designing, building and operating C3I systems.

Comments from DRDC reviewer:

This paper is relatively old as it deals with traditional war structures and organizations. Its content may have to be updated for today's full spectrum type of military operations in theatres. Nevertheless, it is a first effort to identify the sources of complexity that are related to C3I systems. The author claims that no paper appears to address complexity of C3I systems as a separate issue.

<u>Scientific document</u>: The Non-linear Dynamics of War (Beckerman, 1999)

Author(s):

Linda Beckerman (lbeckerman@cfl.rr.com)

From the document:

This paper is about two seemingly antithetical concepts, stability and adaptability in war, as viewed from the perspective of non-linear dynamics. The application of non-linearity, chaos and complexity theory to warfare has enjoyed some attention during the past decade and has the overall positive benefit of causing us to rethink our basic warfighting assumptions. This paper strives to add to that effort and discuss some aspects of nonlinear dynamics that have not been covered before, specifically the relationship between stability and adaptability. It will first

contrast linearity with non-linearity. It will then explore in more depth the non-linear concepts of bifurcation, control parameters, and fitness landscapes along with their ramifications for the evolution of military thought. It does not seek to equate linear with bad, and non-linear with good. This judgmental ascription does not serve the cause, which is to increase the options available so that we can better adapt to changing external circumstances.

<u>Scientific document</u>: Complexity Theory and Al-Qaeda: Examining Complex Leadership (Marion and Uhl-Bien, 2002)

Author(s):

Russ Marion (Marion2@clemson.edu)

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From the document:

We argue that al-Qaeda is a complex organization that is catalyzed by Complex Leadership (or Comple x Adaptive Agents). Complex Leaders foster network construction, build interdependence that enables tension, stimulate bottom- up behavior, spark creativity, and foster distributed intelligence. Evidence to support four propositions is provided: (1) emergence is the product of aggregation that is aided by direct leadership; (2) aggregation is powered by autocatalyzation from catalysts (events) and tags (things, particularly leaders); (3) the nature of network coupling determines emergence and fitness; and (4) human capital is maximally enabled within moderately coupled distributed intelligence networks. The evidence supports these propositions. We trace the emergence of Islamic terrorism from the early years of the 20th century and note its evolution from aggregates to meta-meta-aggregates. We observed the role played by direct and indirect leadership activities. We discuss the powerful aggregating function of catalysts and tags, argue that al-Qaeda's strength derives from its dominantly moderately coupled structure and its distribution of tight and loose structures, and describe how al-Qaeda leadership fostered a distributed intelligence network.

Comments from DRDC reviewer:

The author describes an interesting example of Complex Adaptive System; Al-Qaeda.

<u>Scientific document</u>: Complexity-Based Targeting, New Sciences Provide Effects (Freniere et al., 2003)

Author(s):

Col Robert W. Freniere, Cmdr John Q. Dickmann, Cmdr Jeffrey R. Cares

From the document:

Air campaign planners historically focus on levels of destruction to determine success. The authors argue that by focusing on system complexity (the degree to which the system contains interacting entities with coherent behavior) and system entropy (the amount of work lost within the system when destructive forces are introduced), planners can take advantage of both kinetic and nonkinetic approaches to degrade system function and performance. By focusing on complex system characteristics, planners can induce cascading, chaotic behavior that achieves campaign objectives more dramatically and effectively.

Comments from DRDC reviewer:

This paper brings an interesting view on how to evolve the targeting of the enemy (from serial bombing toward a Complexity-Based Targeting). The author proposes to consider red systems as Complex Adaptive Systems and to reorient the targeting process in such ways that will allow the reduction of its self-adaptation capability. Basic complexity parameters like Grouping, Membership and Identification, Nonlinearity, Rule Sets, Networks and Flow, Competition and Building Blocks are considered as a basis for determining the targeting strategies. This paper would bring a significant contribution in the building of a complexity framework.

Scientific document: Complexity of Military Conflict: Multiscale Complex Systems Analysis of Littoral Warfare (Bar-Yam, 2003d)

Author(s):

Yaneer Bar-Yam (yaneer@necsi.org)

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http://necsi.org/faculty/bar-yam.html

From the document:

The following paper by Professor Bar-Yam discusses the relevance of Multiscale Complex Systems Analysis to a characterization of the differences between conventional and complex warfare challenges, with particular application to littoral warfare. The conclusions suggest that littoral warfare cannot be readily incorporated into Navy operations without considering the specific organizational and technological requirements needed to perform effectively in this high complexity environment. The significance of organizational structure to meeting complex challenges is already apparent from the difference between the organization and training of the Navy and Marines. Beyond the organizational structure, there is a broad relevance of complexity to the selection of appropriate technology and of identifying military objectives in the context of littoral warfare. This paper is presented as an aid both to conceiving of littoral warfare concepts, and more generally as an introduction to the use of the conceptual tools provided by multiscale analysis.

Comments from DRDC reviewer:

This important publication deals with military operations in the context of the new Full Spectrum Operations and Information Age Warfare. In the first part of the document, Dr Bar-Yam first explains the basis of the Multiscale complex systems analysis (MCSA). He then uses MCSA for analysing complex littoral warfare. It is shown that *while hierarchical command systems are appropriate for largest scale impact and simple warfare, distributed control systems is more appropriate for nowadays complex warfare*. *The more complex the threats is, the more complex blue military systems should be. In a high complexity environment, high complexity forces are more capable than low complexity ones.* It is shown that scale (the number of parts of a system to act together in a strictly coordinated way) and complexity (e.g. the variety of possible actions that can be taken) should be used as a measure of force capability in the context of complex military scenarios. *The complexity of a military force is directly linked to its ability to conduct multiple partially independent and coordinated actions of military units. Force incapacitation can take place through reduction in complexity rather than casualties or firepower reduction. Multiscale complex systems analysis (MCSA) provides a formal framework for understanding the interplay of scale and complexity in complex systems and their capabilities in the face of challenges. For military forces, MCSA can provide an understanding of appropriate measures of effectiveness for both conventional and information age military forces. It can also provide guidance about what aspects of conventional military experience remain relevant and which should be changed in the context of complex conflict. Many of these issues revolve around the problem of distributed command, control and coordination of forces.*

<u>Scientific document</u>: Countering Complexity: An Analytical Framework to Guide Counter-Terrorism Policy-Making (Ellis, 2003)

Author(s):

Brent Ellis

From the document:

The development of religiously motivated terrorism has increased the complexity of the terrorist phenomenon. We are currently faced with a wider range of actors with a broader set of motivations, strategies, tactics, organizational structures and goals than ever before. This increased complexity necessitates the development of analytical frameworks that can guide analysis of the terrorist phenomenon to assess terrorist threats and guide counter-terrorism policy-making. Such a framework is developed drawing upon analysis of religiously motivated terrorism in relation to three primary trends in contemporary international terrorism: first, the trend towards the increased lethality of terrorist attacks; second, the increasing threat of the use of weapons of mass destruction; and third, the trend towards decentralizing organization. In each case it is suggested that one can best understand these trends by placing each individual group along a spectrum characterizing either the group's motivation, use of technology or level of centralization. Moreover this framework can be utilized as an organizational principle to allow a structured analysis of an individual group, the threat it represents and the counter-terrorism strategies to be utilized against it.

Scientific document: Observing Al Qaeda through the Lens of Complexity Theory: Recommendations for the National Strategy to Defeat Terrorism (Beech, 2004)

Author(s):

Lieutenant Colonel Michael F. Beech

US Army War College, Carlisle Barracks, Carlisle, PA, US.

From the document:

Al Qaeda's attack on the World Trade Center and the Pentagon on September 11th, 2003 showed the World that a complex network of individuals small groups and organizations coupled by a common sense of purpose and enabled by globalization could deliver a devastating attack upon the most powerful nation on Earth. This paper examines al Qaeda through the lens of Complexity Theory which shows that this organization is a complex adaptive system that emerged as an agent of change within the strategic system of nation states. To defeat al Qaeda or other complex global terrorist networks traditional military strategies reliant on nation state frameworks and determination of centers of gravity and decisive points may not be sufficient. Using the characteristics of Complexity Theory this paper identifies major inputs to expand the current strategy to defeat terrorism. This strategy is focused on diminishing the terrorist network's recuperative and propagative characteristics enabling the emergence of alternatives to terrorism and redressing the sources of anti- Americanism which fuels the network.

Comments from DRDC reviewer:

This document gives an interesting example of a Complex Adaptive System (CAS); Al Qaeda. The author first gives a short description of the Complexity Theory and then investigates Al Qaeda's structures and dynamics to identify factors that are found in CAS. He claims that reductionism is not anymore sufficient to address such complex international organizations. He shows why Al Qaeda is a CAS and he uses the Complexity Theory to identify some elements of solution that would contribute to lower terrorism efficiency and effectiveness. This document is interesting as it uses a concrete example to gives insights on CAS and their properties and characteristics.

Scientific document: Crisis Response Systems through a Complexity Science Lens (Paraskevas, 2005)

Author(s):

Alexandros Paraskevas (aparaskevas@brookes.ac.uk)

Oxford Brookes University, Business School, Department of Hospitality, Leisure and Tourism Management, Tel: 01865-483835, Fax: 01865-483878.

From the document:

Crisis Management is increasingly gaining importance in organizational literature due to the precipitous growth in the sheer number of organizational crises over the past 4 years. The practices currently employed are largely based on a linear command-and-control management approach aiming at very specific results. Modern crises, however, have shown that not only cannot be "managed" but on the contrary have self-perpetuating tendencies. There are several scholars who call for a new approach to crisis management with some of them pointing to the direction of complexity science but only a few are actually using its principles. This paper builds on the work of these scholars and develops it further by offering a complexity perspective for the design of a crisis response system.

<u>Book</u>: Coping with the Bounds: Speculations on Nonlinearity in Military Affairs (Czerwinski and Sands , 1998)

Author(s):

Thomas J. Czerwinski and Jeffrey I. Sands

From CCRP web site (http://www.dodccrp.org/):

The theme of this work is that conventional, or linear, analysis alone is not sufficient to cope with today's and tomorrow's problems, just as it was not capable of solving yesterday's. Its aim is to convince us to augment our efforts with nonlinear insights, and its hope is to provide a basic understanding of what that involves.

<u>Book</u>: Behind the Wizard's Curtain (Krygiel, 1999)

Author(s):

Annette, J. Krygiel

From CCRP web site (http://www.dodccrp.org/):

There is still much to do and more to learn and understand about developing and fielding an effective and durable info structure as a foundation for the 21st century. Without successfully fielding systems of systems, we will not be able to implement emerging concepts in adaptive and agile command and control, nor will we reap the potential benefits of Network Centric Warfare.

<u>Book</u>: Network Centric Warfare (Alberts et al., 1999)

Author(s):

David S. Alberts, John J. Garstka and Frederic P. Stein

From CCRP web site (http://www.dodccrp.org/):

It is hoped that this book will contribute to the preparations for NCW in two ways. First, by articulating the nature of the characteristics of Network Centric Warfare. Second, by suggesting

a process for developing mission capability packages designed to transform NCW concepts into operational capabilities.

<u>Book</u>: Doing Windows: Non-Traditional Military Responses to Complex Emergencies (Hayes and Sands, 1999)

Author(s):

Bradd C. Hayes and Jeffrey I. Sands

From CCRP web site (http://www.dodccrp.org/):

This book provides the final results of a project sponsored by the Joint Warfare Analysis Center. Our primary objective in this project was to examine how military operations can support the long-term objective of achieving civil stability and durable peace in states embroiled in complex emergencies.

<u>Book</u>: Information Age Anthology, Volume III (Alberts and Papp, 2000)

Author(s):

David Stephen Alberts and Daniel S. Papp

From CCRP web site (http://www.dodccrp.org/):

Is the Information Age bringing with it new challenges and threats, and if so, what are they? What sorts of dangers will these challenges and threats present? From where will they (and do they) come? Is information warfare a reality? This publication, Volume II of the Information Age Anthology, explores these questions and provides preliminary answers to some of them.

<u>Book</u>: Understanding Information Age Warfare (Alberts et al., 2001)

Author(s):

David Stephen Alberts, John J. Garstka, Richard E. Hayes and David A.Signori

From CCRP web site (http://www.dodccrp.org/):

This book presents an alternative to the deterministic and linear strategies of the planning modernization that are now an artifact of the Industrial Age. The approach being advocated here begins with the premise that adaptation to the Information Age centers around the ability of an organization or an individual to utilize information.

<u>Book</u>: The NATO Code of Best Practice for C2 Assessment (NATO: 2002)

Author(s):

NATO (http://www.nato.int/)

From CCRP web site (http://www.dodccrp.org/):

To the extent that they can be achieved, significantly reduced levels of fog and friction offer an opportunity for the military to develop new concepts of operations, new organisational forms, and new approaches to command and control, as well as to the processes that support it. Analysts will be increasingly called upon to work in this new conceptual dimension in order to examine the impact of new information-related capabilities coupled with new ways of organising and operating.

<u>Book</u>: Information Age Transformation: Getting to a 21st Century Military (Alberts, 2002)

Author(s):

David Stephen Alberts

From CCRP web site (http://www.dodccrp.org/):

This book is the first in a new series of CCRP books that will focus on the Information Age transformation of the Department of Defense. Accordingly, it deals with the issues associated with a very large governmental institution, a set of formidable impediments, both internal and external, and the nature of the changes being brought about by Information Age concepts and technologies.

<u>Book</u>: Effects Based Operations: Applying Network Centric Warfare to Peace, Crisis, and War (Smith, 2002)

Author(s):

Edward Allan Smith

From CCRP web site (http://www.dodccrp.org/):

This third book of the Information Age Transformation Series speaks directly to what we are trying to accomplish on the "fields of battle" and argues for changes in the way we decide what effects we want to achieve and what means we will use to achieve them.

<u>Book</u>: Power to the Edge (Alberts and Hayes, 2003)

Author(s):

David Stephen Alberts, and Richard E. Hayes

From CCRP web site (http://www.dodccrp.org/):

Power to the Edge articulates the principles being used to provide the ubiquitous, secure, wideband network that people will trust and use, populate with high quality information, and use to develop shared awareness, collaborate effectively, and synchronize their actions.

Comments from DRDC reviewer:

Power to the edge is about changing the way individuals, organizations, and systems relate to one another and work. It involves the empowerment of individuals at the edge of an organization (where the organization interacts with its operating environment to have an impact on that environment) or, in the case of systems, edge devices. The book shows why it is important to break the traditional hierarchical military structure into "relatively decentralize control" during operations. It also gives some hints on how this can be achieved. Power to the edge is the idea behind efficient self-organization of systems during operations.

<u>Book</u>: Complexity Theory and Network Centric Warfare (Moffat, 2003)

Author(s):

James Moffat

From CCRP web site (http://www.dodccrp.org/):

Professor Moffat articulates the mathematical models and equations that clearly demonstrate the relationship between warfare and the emergent behaviour of complex natural systems, as well as a means to calculate and assess the likely outcomes.

Comments from DRDC reviewer:

Physics related to dynamical systems is presented. The content of this document could be reused in further studies of military complex systems.

<u>Book</u>: Terrorism and Counterterrorism: Understanding the New Security Environment, Readings and Interpretations (Howard and Sawyer, 2004)

Author(s):

Russell D. Howard

Reid L. Sawyer

From Amazon.com:

In this newly revised edition of Terrorism and Counterterrorism: Understanding the New Security Environment, Colonel Russell Howard and Major Reid Sawyer have collected original and reprinted articles and essays by political scientists, government officials, and members of the nation's armed forces. The editors and several of the authors write from practical field experience in the nation's war on terrorism. Others have had significant responsibility for planning government policy and responses. The contributors include a majority of the significant names in the field including General Barry McCaffrey, Martha Crenshaw, Bruce Hoffman, Barry Posen, Jessica Stern. Part One of the book analyzes the philosophical, political, and religious roots of terrorist activities around the world and discusses the national, regional, and global effects of historical and recent acts of terrorism. In addition to material on the threats from

suicide bombers, as well as chemical, biological, radiological, and nuclear weapons, there are also important contributions analyzing new and growing threats: narco-terrorism, cyber-terrorism, genomic terrorism, and agro-terrorism. Part Two deals with past, present, and future national and international responses to--and defenses against--terrorism. Essays and articles in this section analyze and debate the practical, political, ethical, and moral questions raised by military and non-military responses (and pre-emptive actions) outside of the context of declared war. Five detailed Appendices: Chronology of Terrorism Incidents, Groups Designated as Foreign Terrorist Organizations, Terrorist Group Profiles, and Weapons of Mass Destruction.

Book: The Information Revolution In Military Affairs (Goldman , 2004)

Author(s):

Emily Goldman

From Amazon.com:

"A formidable collection of authors examine the impact of advanced military information technologies on the leading powers in Asia. Goldman and Mahnken remind us that there is no single revolution in military affairs, but rather very different adjustments by states according to their needs and resources. A substantial contribution to the literature on Asian defense policy, and changes in contemporary military art and science." --Eliot A. Cohen, Director, Strategic Studies Program, The Johns Hopkins School of Advanced International Studies.

Book: The Agile Organization (Atkinson and Moffat, 2005)

Author(s):

Simon Reay Atkinson, James Moffat

From CCRP web site (http://www.dodccrp.org/):

In the spring of 2003, Professor Jim Moffat and Commander Simon Reay Atkinson came together at a Ministry of Defence Conference on Network Connected this and Enabled Capability that and, between the sessions, determined that something was missing." This book contains real-world observations, anecdotes, and historical vignettes that illustrate how organizations and networks function and how the connections between people, nature, societies, beliefs, the sciences, and the military can be understood in order to pursue the goal of an agile organization.

Book: Understanding Command and Control (Alberts and Hayes, 2006)

Author(s):

David Stephen Alberts, and Richard E. Hayes

From CCRP web site (http://www.dodccrp.org/):

Understanding Command and Control is the first in a new series of CCRP Publications that will explore the future of Command and Control. A major discontinuity that will need to be addressed head on will be the definition of the words themselves. This is because the way that these words have been defined drastically limits the available solution space and points us in the wrong direction. This book begins at the beginning: focusing on the problem(s) Command and Control was designed (and has evolved) to solve. It is only by changing the focus from what Command and Control is to why Command and Control is that we will place ourselves in a position to move on.

Book: Network Science (National Academy of Sciences, 2006)

Author(s):

National Academy of Sciences

From (http://www.nap.edu/catalog/11516.html):

The U.S. Army depends on a broad array of interacting physical, informational, cognitive, and social networks. Nevertheless, fundamental understanding about these networks is primitive. This gap between what is known and what is needed to ensure the smooth operation of complex networks makes the Army s transformation to a force capable of network-centric operations (NCO) problematic. To help address this problem, the Army asked the National Research Council to find out whether identifying and funding network science research could help close this gap. This book presents an assessment of the importance and content of network science as it exists today. The book also provides an analysis of how the Army might advance the transformation to NCO operations by supporting fundamental research on networks. The study finds that networks are indispensable to the defense of the United States. In addition, there is no science today that offers the fundamental knowledge necessary to design large, complex networks in a predictable manner. The study also concluded that current federal funding of network research is focused on specific applications and not on advancing fundamental knowledge.

3.10.10 Networks

Scientific document: Discrete Dynamical Networks and their Attractor Basins (Wuensche, 1998)

Author(s):

Andrew Wuensche (wuensch@santafe.edu)

Santa Fe Institute, 1399 Hyde Park Road, Santa Fe, New Mexico 87501 USA

www.santafe.edu/~wuensch/

From the document:

A key notion in the study of network dynamics is that state-space is connected into basins of attraction . Convergence in attractor basins correlates with order -complexity -chaos measures on space-time patterns. A network's ``memory'', its ability to categorize, is provided by the configuration of its separate basins, trees and sub-trees. Based on computer simulations using the software Discrete Dynamics Lab [19], this paper provides an overview of recent work describing some of the issues, methods, measures, results, applications and conjectures.

Scientific document: Classification of Random Boolean Networks (Gershenson, 2002b)

Author(s):

Carlos Gershenson (C.Gershenson@sussex.ac.uk)

School of Cognitive and Computer Sciences, University of Sussex, Brighton, BN1 9QN, U. K.

http://www.cogs.sussex.ac.uk/users/carlos

Center Leo Apostel, Vrije Universiteit Brussel, Krijgskundestraat 33, B-1160 Brussels, Belgium

From the document:

We provide the first classification of different types of Random Boolean Networks (RBNs). We study the differences of RBNs depending on the degree of synchronicity and determinism of their updating scheme. For doing so, we first define three new types of RBNs. We note some similarities and differences between different types of RBNs with the aid of a public software laboratory we developed. Particularly, we find that the point attractors are independent of the updating scheme, and that RBNs are more different depending on their determinism or non-determinism rather than depending on their synchronicity or asynchronicity. We also show a way of mapping non-synchronous deterministic RBNs into synchronous RBNs. Our results are important for justifying the use of specific types of RBNs for modelling natural phenomena.

Scientific document: Information Theory of Complex Networks: On Evolution and Architectural Constraints (Solé and Montoya, 2003)

Author(s):

Ricard V. Solé (2)

Sergi Valverde (1)

(1) ICREA-Complex Systems Lab, Universitat Pompeu Fabra (GRIB), Dr Aiguader 80, 08003 Barcelona, Spain

(2) Santa Fe Institute, 1399 Hyde Park Road, Santa Fe NM 87501, USA

http://www.santafe.edu/

From the document:

Complex networks are characterized by highly heterogeneous distributions of links, often pervading the presence of key properties such as robustness under node removal. Several correlation measures have been defined in order to characterize the structure of these nets. Here we show that mutual information, noise and joint entropies can be properly defined on a static graph. These measures are computed for a number of real networks and analytically estimated for some simple standard models. It is shown that real networks are clustered in a well-defined domain of the entropy-noise space. By using simulated annealing optimization, it is shown that optimally heterogeneous nets actually cluster around the same narrow domain, suggesting that strong constraints actually operate on the possible universe of complex networks. The evolutionary implications are discussed.

Scientific document: The Topology of Large-Scale Engineering Problem-Solving Networks (Braha and Bar-Yam, 2004b)

Author(s):

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(1) Faculty of Engineering Sciences, Ben-Gurion University, P.O.Box 653, Beer-Sheva 84105, Israel.

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http://necsi.org/faculty/bar-yam.html.

(3) Department of Molecular and Cellular Biology, Harvard University, Cambridge, MA 02138, U.S.A.

From the document:

The last few years have led to a series of discoveries that uncovered statistical properties, which are common to a variety of diverse real-world social, information, biological and technological networks. The goal of the present paper is to investigate, for the first time, the statistical properties of networks of people engaged in distributed problem solving and discuss their significance. We show that problem-solving networks have properties (sparseness, small world, scaling regimes) that are like those displayed by information, biological and technological networks. More importantly, we demonstrate a previously unreported difference between the distribution of incoming and outgoing links of directed networks. Specifically, the incoming link distributions have sharp cutoffs that are substantially lower than those of the outgoing link distributions (sometimes the outgoing cutoffs are not even present). This asymmetry can be explained by considering the dynamical interactions that take place in distributed problem solving, and may be related to differences between the actor's capacity to process information provided by others and the actor's capacity to transmit information over the network. We

conjecture that the asymmetric link distribution is likely to hold for other human or non-human directed networks as well when nodes represent information processing/using elements.

Scientific document: Delays, connection topology, and synchronization of coupled chaotic maps (Atay et al., 2004)

Author(s):

Fatihcan M. Atay, Jürgen Jost, Andreas Wende

From the document:

We consider networks of coupled maps where the connections between units involve time delays. We show that, similar to the undelayed case, the synchronization of the network depends on the connection topology, characterized by the spectrum of the graph Laplacian. Consequently, scale-free and random networks are capable of synchronizing despite the delayed flow of information, whereas regular networks with nearest-neighbor connections and their small-world variants generally exhibit poor synchronization. On the other hand, connection delays can actually be conducive to synchronization, so that it is possible for the delayed system to synchronize where the undelayed system does not. Furthermore, the delays determine the synchronized dynamics, leading to the emergence of a wide range of new collective behavior which the individual units are incapable of producing in isolation.

Scientific document: Information Flow Structure in Large-Scale Product Development Organizational Networks (Braha and Bar-Yam, 2004)

Author(s):

Dan Braha (1,2)

Yaneer Bar-Yam (2,3)

(1)Faculty of Engineering Sciences, Ben-Gurion University, P.O.Box 653,

Beer-Sheva 84105, Israel, (brahad@bgumail.bgu.ac.il, braha@necsi.org)

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(3) Department of Molecular and Cellular Biology, Harvard University,

Cambridge, MA 02138, U.S.A.

From the document:

In recent years, understanding the structure and function of complex networks has become the foundation for explaining many different real- world complex social, information, biological and technological phenomena. Techniques from statistical physics have been successfully applied to the analysis of these networks, and have uncovered surprising statistical structural properties that have also been shown to have a major effect on their functionality, dynamics, robustness, and fragility. This paper examines, for the first time, the statistical properties of strategically important complex organizational information-based networks -- networks of people engaged in distributed product development -- and discusses the significance of these properties in providing insight into ways of improving the strategic and operational decision-making of the organization. We show that the patterns of information flows that are at the heart of large-scale product development networks have properties that are like those displayed by information, biological and technological networks. We believe that our new analysis methodology and empirical results are also relevant to other organizational information-based human or nonhuman networks.

Scientific document: Analytically solvable model of probabilistic network dynamics (De Aguiar et al., 2005)

Author(s):

M. A. M. de Aguiar (1,2)

Irving R. Epstein (1,3)

Yaneer Bar-Yam (1)

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(2) Instituto de Física Gleb Wataghin, Universidade Estadual de Campinas, 13083-970 Campinas, São Paulo, Brazil

(3) Department of Chemistry, MS015, Brandeis University, Waltham, Massachusetts 02454, USA

From the document:

We present a simple model of network dynamics that can be solved analytically for fully connected networks. We obtain the dynamics of response of the system to perturbations. The analytical solution is an excellent approximation for random networks. A comparison with the scale-free network, though qualitatively similar, shows the effect of distinct topology.

3.10.11 Organizations

Scientific document: Integrating Complexity Theory, Knowledge Management and Organizational Learning (McElroy, 2000)

Author(s):

Mark W. McElroy.

From the document:

Chronicles the unfolding convergence of thinking and practice behind knowledge management, organizational learning and complexity theory. Of particular interest are the roles that knowledge management and complexity theory play in this impending consilience of ideas. On the one hand, knowledge management is anxious to rid itself of its overly technology-centric reputation in favor of promoting the role it can play in furthering organizational learning. On the other, complexity theory, a confident solution in search of unorthodox problems, has discovered its own true place in the world, an explanation for the means by which living systems engage in adaptive learning ± the seminal source of social cognition in living systems.

Scientific document: Systems Engineering Approach for Modeling an Organizational Structure (Rushton et al., 2002)

Scientific document: Complex Adaptive Systems, Attractors, and Patching: a Complex Systems Science Analysis of Organizational Change (Shetler, 2002)

Author(s):

Judith Campbell Shetler

Graduate School of the University of Texas, Austin, USA.

From the document:

This study focuses the lens of complex systems science (CSS) on the widely varying experiences of interventionary change in organizations. Two very different types of organizations are studied. Instances of attempted Total Quality Management-type change at both the organizational and project levels in each firm are analyzed, with one attempt successful, the other not. The complex adaptive system model of CSS, and two of its lower level constructs: attractors and patching, are applied metaphorically to analyze the change experiences of the two organizations. The analysis emphasizes the essential role of communicative interaction in the natural dynamics of social change. The CSS focus offers new analytical insights into the unpredictable nature of organizational change processes, and suggests the potential aid such insights might offer. Implications for theory and practice in the application of complex systems science to organizational theory, with am emphasis on communication, are discussed, and areas for further research are suggested.

Scientific document: Complexity and Innovation: Army Transformation and the Reality of War (Calhoun, 2004)

Author(s):

Major Mark T. Calhoun

School of Advanced Military Studies, Army Command and General Staff College, Fort Leavenworth, Kansas, US.

From the document:

On 12 October 1999, the U.S. Army began a journey down a new path to innovation, when General Eric Shinseki presented his vision of Army Transformation at the 45th annual meeting of the Association of the United States Army. In this speech, General Shinseki described the Army as an organization consisting of heavy forces with excellent staying power but poor strategic responsiveness, light forces with excellent responsiveness but poor staying power, and a logistics system with an excessively large footprint. His proposed solution, a comprehensive change of the Army resulting in full-spectrum dominance and strategic responsiveness, would occur so quickly as to "be unnerving to some." While this prediction has turned out in many ways to be true, it is not necessarily the speed of change that is unnerving to many of the people studying Army Transformation. This study's research question is, "Does Army Transformation embody the concepts of complexity theory as applied to organizational design?" Because Army Transformation lacks a clearly articulated theoretical framework, seeking to develop a Future Force in the absence of a specific operational design and supporting doctrine, the process is subordinated to the whims of Army culture and parochial bias. Complexity science is one possible source of sound theoretical principles that could provide a guiding framework to the transformation process. The study demonstrates that Army Transformation is in conflict with all of the major principles of dynamic systems, complex networks, chaos, and complexity theory. Several recommendations are provided in Chapter six. These recommendations focus on culture, by attempting to influence discourse so that it is at less risk of severe divergence with the reality of the complex world. In order to bring Army Transformation in line with CRP theory, the Army should: (1) facilitate emergence by encouraging the innovative efforts of change agents distributed throughout all levels of the Army; (2) modify education and training systems to promote adoption of a complexity CBM; and (3) abandon the speculative pursuit of the "Information-RMA" and its associated technological panaceas.

Comments from DRDC reviewer:

This report should be read by Canadian stakeholders aiming at improving military acquisition and operations. The report first defines what is meant by army transformation and describes some associated problems. The importance of culture in military organizations is the investigated. An interesting review of Complexity Theory and complex systems is then presented. Among other things, the author makes a parallel between military organizations and complex systems. He presents and defines three conditions as necessary for self-organization: 1) container, 2) differences and 3) transforming exchanges.

<u>Scientific document</u>: Revisiting the Notion of System – Organizations and Enterprise as Systems (Faisandier, 2005)

Author(s):

Faisander (alain.faisandier@mapsysteme.com)

MAP SYSTEME - 2, chemin de la Serre - 31450 BELBERAUD – FRANCE

From the document:

This paper reports on a study performed for NATO about the opportunity to tailor and use the ISO/IEC 15288 standard as well as Systems Engineering concepts for such an Organization. The objective of applying the standard and SE concepts was to help prioritise, rationalise or align processes, activities and organisations. The result of this study was a report for NATO including explanations of the concepts and their potential application, rules for tailoring the standard, as well as a set of recommendations. The recommendations are not reproduced in this paper; only the "system aspects" are considered here, along with its application to NATO as a complex Organization. Some considerations about ANSI/EIA 632 are added to introduce the notion of "enabling product" and "enabling systems". This paper discusses how the notion of System can be applied to an Organization and extends the application to Enterprises. The discussion revisits the concept of System in light of current engineering studies and coming back to fundamentals, provides a more precise and more complete definition of this notion. This enhanced definition of System rationalizes the engineering of any kind of system and particularly brings benefits to Organizations and industrial Enterprises viewed as systems. Whether the idea of engineering Organizations and Enterprises as systems is attractive to engineers or others raises questions of feasibility and relevance. Organizations and Enterprises are composed of human beings, hence, defined as "Human Systems"; so the paper ends with some words about human factors that could help or hinder the adoption of these useful rational ideas.

Comments from the DRDC reviewer:

The idea of considering organizations and people as part of systems appears to be aligned with the holistic approach that tries to concurrently consider “all” involved interacting and dynamical parts as an interacting whole.

Book: The Fifth Discipline: The Art and Practice of the Learning Organization (Senge, 1994)

Author(s):

Peter M. Senge

From Amazon.com

Peter Senge, founder of the Center for Organizational Learning at MIT's Sloan School of Management, experienced an epiphany while meditating one morning back in the fall of 1987. That was the day he first saw the possibilities of a "learning organization" that used "systems thinking" as the primary tenet of a revolutionary management philosophy. He advanced the concept into this primer, originally released in 1990, written for those interested in integrating his philosophy into their corporate culture. The Fifth Discipline has turned many readers into true believers; it remains the ideal introduction to Senge's carefully integrated corporate framework, which is structured around "personal mastery," "mental models," "shared vision," and "team learning." Using ideas that originate in fields from science to spirituality, Senge explains why the learning organization matters, provides an unvarnished summary of his management principals, offers some basic tools for practicing it, and shows what it's like to

operate under this system. The book's concepts remain stimulating and relevant as ever. --Howard Rothman

Comments from the DRDC reviewer:

This book is often cited in the scientific literature.

<u>Book</u>: The Fifth Discipline Fieldbook: Strategies and Tools for Building a Learning Organization (Senge et al., 1994)

Author(s):

Peter M. Senge, Art Kleiner and Charlotte Roberts

From Amazon.com

Senge's best-selling The Fifth Discipline led Business Week to dub him the "new guru" of the corporate world; here he offers executives a step-by-step guide to building "learning organizations" of their own. Shows how to create an organization of learners where memories are brought to life, where collaboration is the lifeblood of every endeavor, & where the tough questions are fearlessly asked. Audio tape. --This text refers to an out of print or unavailable edition of this title.

Comments from the DRDC reviewer:

This book is often cited in the scientific literature.

<u>Book</u>: The Edge of Organization: Chaos and Complexity Theories of Formal Social Systems (Marion, 1999)

Author(s):

Russ Marion

From Amazon.com

“What Newton’s Principia was to his natural science colleagues, Russ Marion’s The Edge of Organization is to today’s social scientists. This book clearly elucidates the arrival of the social sciences at the end of the alley of modernism but then presents us with the tools and ideas to climb out of a dead end, rise above old limitations, and take flight for new horizons bright with promise for advancing both theory and praxis. . . . For social scientists, it is both the most relevant and most easily apprehended treatment to date of the totality of chaos and complexity theory and technique.” --Raymond A. Eve, Editor, Chaos, Complexity, and Sociology The Edge of Organization offers a readable, comprehensive, and integrated overview of the new sciences of chaos and complexity. Author Russ Marion describes formal and social organizations from the perspective of chaos and complexity theories. His multidisciplinary approach will appeal to students and scholars across a wide range of social sciences. This book is generously illustrated and includes comprehensive references plus an annotated bibliography of useful books and

articles. The Edge of Organization will appeal to students and professionals in sociology, management/ organization studies, management studies, marketing, political science, public administration, and psychology.

Comments from Mario Paolucci (http://jasss.soc.surrey.ac.uk/5/4/reviews/paolucci.html):

The purpose of this book is to promote and support the application of complex systems theory to organisation theory. There are good motivations for trying to do so; complexity is advocated by many as a tool for bridging the gap between more traditional methodologies, employed in the social sciences in general, and the more formalised and mathematically rigorous ("hard") sciences. After strong growth in the second half of the '80s (see for example Anderson et al. 1988), followed by a period of relative calm, complexity and complex (adaptive) systems are now rallying their strength. The field is currently entering a new period of expansion, as evidenced by the significant presence of EC funded projects and networks in the field (Existence, COSI and so on). The wide applicability of complexity theories and the need for formalisation felt in organisation theory makes this an interesting and potentially fruitful match. For example, the journal Emergence published a discussion about this interaction in its first number which came out at almost exactly the same time as Marion's book.

Book: Strategic Management and Organizational Dynamics: The Challenge of Complexity (Stacey, 1999)

Author(s):

Ralph D. Stacey

From Amazon.com

Ralph Stacey continues to question the view that organisations operate and succeed in relatively stable environments. He argues that in order to succeed in uncertainty and continual change, organisations need to create new perspectives and learn from the chaos within which they operate. This new edition of Strategic Management and Organisational Dynamics continues to focus on this radically different approach to strategic management. The central tenets of this approach have to do with unpredictability and the limitations of control, and therefore it argues against the rational models of planning and control covered in other strategy textbooks. This is done by emphasising the importance of narrative, conversation and learning from one's own experience as the central means by which we can gain understanding and knowledge of strategy in organisations.

Book: Complex Responsive Processes in Organizations: Learning and Knowledge Creation (Stacey, 2001)

Author(s):

Ralph D. Stacey

From Amazon.com

(Taylor and Francis) Argues that most of the literature on complex responsive processes in organizations reflects systems thinking, which the authors view as untenable. Provides an alternative perspective which draws on the complexity sciences as a domain for analogies with human action in organizations.

<u>Book</u>: Facilitating Organization Change: Lessons from Complexity Science (Olson and Eoyang, 2001)

Author(s):

Edwin E. Olson and Glenda H. Eoyang

From Amazon.com

*Looking for a highly effective alternative to traditional change models? Finally, an alternative to traditional change models-the science of complex adaptive systems (CAS). The authors explain how, rather than focusing on the macro "strategioc" level of the organization system, complexity theory suggests that the most powerful change processes occur at the micro level where relationship, interaction and simple rules shape emerging patterns. * Details how the emerging paradigm of a CAS affects the role of change agents * Tells how you can build the requisite skills to function in a CAS * Provides tips for thriving in that new paradigm "Olson and Eoyang do a superb job of using complexity science to develop numerous methods and tools that practitioners can immediately use to make their organizations more effective." --Kevin Dooley, Professor of Management and Industrial Engineering, Arizona State University.*

<u>Book</u>: Complexity and the Experience of Managing in Public Sector Organization (Stacey, 2005a)

Author(s):

Ralph D. Stacey

From Amazon.com

The perspective of complex responsive processes draws on analogies from the complexity sciences, bringing in the essential characteristics of human agents, understood to emerge in social processes of communicative interaction and power-relating. The result is a way of thinking about life in organizations that focuses attention on how organizational members cope with the unknown as they perpetually create organizational futures together. Providing a natural successor to the Editors' earlier series (Complexity and Emergence in Organizations) this series, Complexity as the Experience of Organizing, aims to take this work further by taking very seriously the experience of organizational practitioners, and showing how taking the perspective of complex responsive processes yields deeper insight into practice and so develops that practice.

<u>Book</u>: A Complexity Perspective on Researching Organizations: Taking Experience Seriously (Stacey, 2005b)

Author(s):

Ralph D. Stacey

From Amazon.com

The perspective of complex responsive processes draws on analogies from the complexity sciences, bringing in the essential characteristics of human agents, understood to emerge in social processes of communicative interaction and power-relating. The result is a way of thinking about life in organizations that focuses attention on how organizational members cope with unknown as they perpetually create organizational futures together. Providing a natural successor to the Editors' earlier series (Complexity and Emergence in Organizations) this series Complexity as the Experience of Organizing, aims to take this work further by taking very seriously the experience of organizational practitioners, and showing how taking the perspective of complex responsive process yields deeper insight into practice and so develops that practice. In this book, all of the contributors work as leaders, consultants or managers in organizations. They provide narrative accounts of their actual work addressing questions such as: How does the work of the researcher actually assist managers when the uncertainty is so great that they do no know what they are doing yet? What does research in organizations actually achieve? If patters of human interaction produced nothing but further patterns of human interaction, in the creation of which we are all participating, is there a detached way of understanding organizations from the position of the objective observer? In considering such questions in terms of their daily experience, the contributors explore how the perspective of complex responsive processes assists them to make sense of their experience and so to develop their practice. A Complexity Perspective on Researching Organizations offers a different method for making sense of experience in a rapidly changing world by using reflective accounts of ordinary everyday life in organizations rather than idealized accounts. The editors' commentary introduces and contextualizes these experiences as well as drawing out key themes for further research. A Complexity Perspective on Researching Organizations will be of value to readers from amongst those academics and business school students and practitioners who are looking for reflective accounts of real life experiences of researching in organizations, rather than further prescriptions of what life in organizations ought to be like.

3.10.12 Project Management

Scientific document: Chaos Theory and Project Management: A perspective on managing the complex project

Author(s):

Donna Fitzgerald and Janet Bardyn,

Can be found at the following web site (2006):

http://www.nimblepm.com/writings/chaostheory.html

From the document:

Complexity theory, second-order cybernetics, non-linearity and chaos theory are all terms that attempt to describe the non-Newtonian fact that things are messy around the edges, and that the

"messiness" tends to not only disrupt the linearity of a system, but over time, through the result of both negative and positive feedback, will actually cause the system to change/adapt. What do these theories mean to us as project managers? Dave Olsen in his book Exploiting Chaos: Cashing in on the Realities of Software Development describes our current situation as one of existing within a structure that includes a number of paradigms. Our first paradigm, the one most of us confront on a daily basis, is "Murphy was right". We live with the disaster of the week and spend our time madly scurrying around putting out fires. The area of orderly space in this paradigm is small and the disorderly space is large. Our second paradigm is that of Newtonian physics or what for project managers approximates the Holy Grail. This paradigm tells us that the world is really an orderly place and if we just had better tools and better resources we could virtually eliminate the "chaos" or disorderly feedback that we live with on a normal basis. According to this view of things the area of orderly space is large and the area of surrounding disorganization is small. Our third paradigm is that of complexity theory itself which tells us that we are not crazy and that the reason Murphy was right is that "Projects" are non-linear complex systems that respond to different rules than we were led to believe. By recognizing this fact as REALITY (i.e. inherent in the very nature of the process) rather than as something we are cursed with because we have not done a better job of planning or execution, our paradigm will shift, and we will work with, rather than against, the non-linearity of the project management process.

Scientific document: On Uncertainty, Ambiguity, and Complexity in Project Management (Pich et al., 2002)

Author(s):

Michael T. Pich (michael.pich@insead.edu)

INSEAD, 1 Ayer Rajah Avenue, Singapore 138676

Christoph H. Loch (christoph.loch@insead.edu)

INSEAD, Boulevard de Constance, 77305 Fontainebleau Cedex, France

Arnoud De Meyer (arnoud.de.meyer@insead.edu)

INSEAD, 1 Ayer Rajah Avenue, Singapore 138676

From the document:

This article develops a model of a project as a payoff function that depends on the state of the world and the choice of a sequence of actions. A causal mapping, which may be incompletely known by the project team, represents the impact of possible actions on the states of the world. An underlying probability space represents available information about the state of the world. Interactions among actions and states of the world determine the complexity of the payoff function. Activities are endogenous, in that they are the result of a policy that maximizes the expected project payoff. A key concept is the adequacy of the available information about states of the world and action effects. We express uncertainty, ambiguity, and complexity in terms of information adequacy. We identify three fundamental project management strategies: instructionism, learning, and selectionism. We show that classic project management methods

emphasize adequate information and instructionism, and demonstrate how modern methods fit into the three fundamental strategies. The appropriate strategy is contingent on the type of uncertainty present and the complexity of the project payoff function. Our model establishes a rigorous language that allows the project manager to judge the adequacy of the available project information at the outset, choose an appropriate combination of strategies, and set a supporting project infrastructure—that is, systems for planning, coordination and incentives, and monitoring.

3.10.13 Social Sciences

Scientific document: Modelling social systems as complex: Towards a social simulation meta-model (Goldspink, 2000)

Author(s):

Chris Goldspink (cgold@ozemail.com.au)

PO Box 591, Tanunda, South Australia 5352.

From the document:

There is growing interest in extending complex systems approaches to the social sciences. This is apparent in the increasingly widespread literature and journals that deal with the topic and is being facilitated by adoption of multi-agent simulation in research. Much of this research uses simple agents to explore limited aspects of social behaviour. Incorporation of higher order capabilities such as cognition into agents has proven problematic. Influenced by AI approaches, where cognitive capability has been sought, it has commonly been attempted based on a 'representational' theory of cognition. This has proven computationally expensive and difficult to implement. There would be some benefit also in the development of a framework for social simulation research which provides a consistent set of assumptions applicable in different fields and which can be scaled to apply to simple and more complex simulation tasks. This paper sets out, as a basis for discussion, a meta-model incorporating an 'enactive' model of cognition drawing on both complex system insights and the theory of autopoiesis. It is intended to provide an ontology that avoids some of the limitation of more traditional approaches and at the same time providing a basis for simulation in a wide range of fields and pursuant of a wider range of human behaviours.

Scientific document: A Framework for the Study of Individual Behavior and Social Interactions (Durlauf, 2001)

Author(s):

Steven N. Durlauf (sdurlauf@ssc.wisc.edu)

Department of Economics, University of Wisconsin, 1180 Observatory Drive, Madisson, WI 53706-1393, USA.

From the document:

Recent work in economics has begun to integrate sociological ideas onto the modelling of individual behavior. In particular, this new approach emphasizes how social context and social interdependences influence the ways in which individuals make choices. This paper provides an overview of an approach to integrating theoretical and empirical analysis of such environments. The analysis is based on a framework due to Brock and Durlauf (2000a, 2000b). Empirical evidence on behalf of this perspective is assessed and some policy implications are explored.

Scientific document: Modelling Complex Socio-Technical Systems Using Morphological Analysis (Ritchey, 2003)

Author(s):

Tom Ritchey

www.swemorph.com

3.10.14 System Engineering and Architecting

Scientific document: Architecting Principles for Systems-of-Systems (Maier, 1999)

Author(s):

Mark W. Maier

CH1-460, The Aerospace Corporation, Chantilly, VA 20151

From the document:

While the phrase "system-of-systems" is commonly seen, there is less agreement on what they are, how they may be distinguished from "conventional" systems, or how their development differs from other systems. This paper proposes a definition, a limited taxonomy, and a basic set of architecting principles to assist in their design. As it turns out, the term system-of-systems is infelicitous for the taxonomic grouping. The grouping might be better termed "collaborative systems." The paper also discusses the value of recognizing the classification in system design, and some of the problems induced by misclassification. One consequence of the classification is the identification of principal structuring heuristics for system-of-systems. Another is an understanding that, in most cases, the architecture of a system-of-systems is communications. The architecture is nonphysical, it is the set of standards that allow meaningful communication among the components. This is illustrated through existing and proposed systems.

Comments from DRDC reviewer:

This book is often cited in the scientific literature. Very interesting for engineers and architects.

Scientific document: Application of Complex Systems Science to Systems Engineering (Beckerman, 2000)

Author(s):

Linda P. Beckerman

Science Applications International Corporation, 12479 Research Parkway, Orlando, FL, 32826

From the document:

This article discusses how we can modify our approaches for performing systems engineering by incorporating the ideas inherent in the complex system science approach. The reductionist approach is described in terms of its effect on the classical systems engineering efforts. The holistic approach is then described with emphasis on the concepts of emergence and nonlinear, dynamic behavior. Having laid this groundwork, the paper then will discuss a melding of the reductionist and holistic approaches. This paper will suggest how we might modify the systems engineering processes used today to gain a whole-brained approach that bridges the gulf between these two strategies.

Comments from DRDC reviewer:

The author integrates some aspects of the Complexity Theory into the classical Systems Engineering. Using one concrete example, she explains why the reductionism approach induces rippling problems through the entire development life cycle. She then proposes the use of both reductionism and holism. As it would be very hard in Systems Engineering to discover local rules that give rise to emergent properties, she proposes to start with wanted or desired emergent properties, and through the reductionism approach, identify and develop the components and behaviours that give rise to them. In order to avoid losing holistic view at the lower levels of development, she proposes to add back in the holistic view at these lower levels. Three main recommendations are made to achieve this, they are: *1) Employ a Concept of Operations Type Approach at the Lower Hierarchical Levels, 2) Define all interactions (not just pairwise sets) and their corresponding emergent behaviours, and 3) Apply the emergent story used to plan integration test activities upstream during design.*

<u>Scientific document</u>: On the Systems Engineering and Management of Systems of Systems and Federations of Systems (Sage and Cuppan, 2001)

Author(s):

Andrew P. Sage and Christopher D. Cuppan

Department of Systems Engineering and Operations Research, George Mason University, Fairfax, VA, USA.

From the document:

This paper is concerned with the engineering of systems that are themselves comprised of other component systems, and where each of the component systems serves organizational and human purposes. These component purposes may be locally managed and optimized independently, or nearly so, of the objectives to be met by the composite system. There are a number of inherent

characteristics of these systems, and such related terms as systems of systems (SOS) or federations of systems (FOS) or federated systems of systems (F-SOS) are often used to characterize them. It is asserted that the resultant systems generally possess the characteristics of complex adaptive systems. We provide an overview of the literature describing these engineering efforts and provide plausible strategies for systems engineering and management of SOS and FOS that are based on the principles of a "new federalism". Finally, the implications of these plausible SOS and FOS systems engineering and management concepts are discussed with emphasis on evolutionary acquisition in the style of DoD and Intelligence Community related programs.

<u>Scientific document</u>: System of Systems (SoS) enterprise systems engineering for information-intensive organizations (Garlock and Fenton, 2001)

Author(s):

Paul G. Carlock (paul.carlock@trw.com)

TRW Intelligence Systems Division, 12011 Sunset Hills Road, Reston, VA 20190

Robert E. Fenton

Intelligence Systems Division, 12011 Sunset Hills Road, Reston, VA 20190

From the document:

This article describes the emerging roles of the systems engineering (SE) function in supporting enterprise management in information-intensive organizations. "Enterprise Systems Engineering" (ESE) comprises three major roles or "levels" of systems engineering for successful and efficient development or procurement of large complex systems of systems (SoS). While the authors' experience focuses predominantly on government organizations acting as their own SoS integrators, the SoS ESE concept has generic applicability for any organization, public or private, seeking to attain competitive advantage through leveraging of information technology resources and systems. The processes and tools described here have been developed and successfully employed to facilitate government project management and investment decisions and control. [Carlock and Decker, 1998] This paper describes a formal three-level SoS ESE process that, at the top level, organizes and maintains all of the details of the enterprise-wide SoS architecture and strategic development plan in a flexible framework that accommodates the changes expected over a long SoS evolution. The information maintained in this framework allows the organization to know where it is going, how and when it is going to get there, the required capabilities and interfaces of each SoS component, and the impact of changes to system requirements, budgets, schedules, etc., on the overall SoS. The middle level processes allow the organization to perform trade studies among alternative solutions to implement required capabilities based on what is best for the enterprise-wide SoS rather than just local considerations. The end result of the middle level processes is a selected and approved solution and its associated cost, schedule, benefits, and technical baselines. The third level processes implement the approved solutions in accordance with the approved baselines.

<u>Scientific document</u>: Capability Dynamics: An Approach to Capability Planning and Development in Large Organizations (Flint and Boughton, 2001)

Author(s):

Shayne R. Flint and Clive V. Boughton

Department of Computer Science, Australian National University, ACT 0200, Australia.

From the document:

This paper describes Capability Dynamics, a synthesis of system dynamics, control, agent based simulation and distributed systems techniques, which aims to increase the likelihood that decisions made throughout and at all levels of an organisation contribute in a coordinated way to satisfying the organisation's requirements and those of its stakeholders. The focus of Capability Dynamics is on the identification of systems that need to be developed, modified and retired within a whole-of-capability, and whole-of-life context of required capabilities and evaluation criteria. It is left to other research and existing systems engineering practice to improve individual systems within this context.

Comments from DRDC reviewer:

The authors consider organizations as a System of Systems. This is of particular interest when dealing with high complexity projects. Links are made between Complexity Theory and large complex organizations.

<u>Scientific document</u>: Effective Engineering Decisions Through Structured Collaboration (Wilson, 2002)

Author(s):

Mark A. Wilson,

Center for Systems Management, 13873, Park Center Road, Suite 15, Herndon, VA, USA.

From the document:

This paper describes a methodology for engineering decision-making through structured collaboration. This collaborative decision engineering methodology has been effective in both government and commercial arenas on a wide range of programs. By thinking about the decision as a three step process of: (1) framing the decision to be made, (2) generating alternatives, and (3) deciding the course of action, decision makers can harness group dynamics to help achieve the goal of implementing engineering decisions that work and last.

<u>Scientific document</u>: A Complex Systems Perspective on Collaborative Design (Klein et al., 2002)

Author(s):

Mark Klein

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http://necsi.org/faculty/bar-yam.html

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Hiroki Sayama

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From the document:

Almost all complex artifacts nowadays, including physical artifacts such as airplanes, as well as informational artifacts such as software, organizational designs, plans and schedules, are created via the interaction of many, sometimes thousands of participants, working on different elements of the design. This collaborative design process is typically expensive and time-consuming because strong interdependencies between design decisions make it difficult to converge on a single design that satisfies these dependencies and is acceptable to all participants. Complex systems research concerning the generic dynamics of distributed networks has much to offer to the understanding of this process. This paper describes some insights derived from this novel perspective.

Scientific document: System of Systems Engineering (Keating et al., 2003)

Author(s):

Charles Keating, Ralph Rogers, Resit Unal, David Dryer, Andres Sousa-Poza, Robert Safford, William Peterson, and Ghaith Rabadi

Old Dominion University.

From the document:

The purpose of this article is to develop the concept, foundations, research directions, and practice implications for System of Systems Engineering (SoSE). First, we introduce the nature of the complex systems problems faced by SoSE. Second, current perspectives of system of systems

are explored. These perspectives are synthesized to a set of common themes in the literature and shortcomings in the current state of SoSE are identified. Third, we provide our perspective of SoSE, with implications for design, deployment, operation, and transformation of complex systems of systems. Fourth, we propose the structure for a research agenda to advance the knowledge and practice of SoSE. We close by developing implications of SoSE for systems engineering practitioners.

Scientific document: A Model of System Coherence (Aslaksen, 2003)

Author(s):

Erik W. Aslaksen

Sinclair Knight Merz Pty. Ltd., P.O. Box 164, St Leonards, New South Wales, 1590 Australia.

From the document:

Modeling of system behavior is an important part of the systems engineering methodology. One characteristic of system behavior that is common to a large class of systems is coherence, and we propose a simple model of coherent behavior, which at the same time gives an operational definition of system coherence. Results of simulation of system behavior obtained using this model are presented, and they display all the features normally associated with cooperative behavior. This indicates that with the proposed definition, coherence could become a useful system parameter.

Scientific document: Advancing Systems Engineering for System-of-Systems Challenges (Chen and Clothier, 2003)

Author(s):

Pin Chen (pin.chen@dsto.defence.gov.au)

Jennie Clothier

Joint Systems Branch, DSAD, Defence Science & Technology Organization, Department of Defence, DSTO C3 Research Center, Fenwick Park, Canberra, ACT 2600, Australia.

From the document:

Engineering activities in future organization development, including various information-based systems, vary, but all result in evolutions of an organization, its capabilities and systems. These evolutions occur in a context of Systems-of-Systems (SoS) where the organization must maintain a sustained, sustainable, and controlled SoS evolution as a whole. This paper presents an understanding of SoS challenges to the application of Systems Engineering (SE) in organizational evolutionary development and discusses the difference between "developing a SoS" and " developing systems in a SoS context" from an SE management perspective. A new approach to SE process organization and management is presented in order to help an organization cope with the high complexity of SoS evolutions and improve its architecture practice. Philosophically different

from many SoS SE studies that consider mainly how to develop a SoS, the new approach is to add a dimension or components of SE practice at the organization level that is aimed at creating a better engineering environment to enable effective applications of traditional SE practice in implementing SoS evolutions.

<u>Scientific document</u>: Expanding the role of systems engineers in the age of escalating complexity (Ren, 2003)

Author(s):

Chiang H. Ren (ChiangRen@keplerresearch.com.)

From the document:

The accomplishments of scientists conducting complex systems research could significantly expand the role of systems engineers currently wrestling with more narrowly defined complex systems. The rapid growth of problems extending from newly formed complex systems in society, economic activities, and geopolitical dynamics argues further for the immediate fusion of scientific insight with practical engineering approaches for problem solving. In supporting this new role for systems engineers, a new class of complex systems engineering tools, along with new analytical techniques, are envisioned. Such tools and techniques can further support the continuing efforts of scientists in unraveling the mysteries of highly complex self-forming and self-organizing systems.

<u>Scientific document</u>: Synthesizing executable models of object oriented architectures (Wagenhals et al., 2003)

Author(s):

Lee W. Wagenhals, Sajjad Haider, Alexander H. Levis

Systems Architecture Laboratory, C3I Center, MSN 4B5, George Mason University, Fairfax, VA 22030-4444.

From the document:

The United States Department of Defense (DoD) has mandated the development of Command, Control, Communications Computers, Intelligence, Surveillance, and Reconnaissance (C4ISR) Architectures to support the acquisition of systems that are interoperable and will meet the needs of military coalitions. This paper provides a general description of an architecting process based on the object oriented Unified Modeling Language (UML) that includes three phases: analysis, synthesis, and evaluation. It then provides a rationale for style constraints on the use of UML artifacts for representing DoD C4ISR architectures. Finally the paper describes both a mapping between the UML artifacts and an executable model based on Colored Petri nets that can be used for logical, behavioral, and performance evaluation of the architecture. A procedure for the conversion is also provided.

Scientific document: When Systems Engineering Fails --- Toward Complex Systems Engineering (Bar-Yam, 2003e)

Author(s):

Yaneer Bar-Yam

New England Complex Systems Institute, 24 Mt. Auburn St., Cambridge, MA 02138, TEL 617-547-4100 FAX 617-661-7711

necsi@necsi.org

http://necsi.org/faculty/bar-yam.html.

From the document:

We review the lessons learned from problems with systems engineering over the past couple of decades and suggest that there are two effective strategies for overcoming them: (1) restricting the conventional systems engineering process to not-too-complex projects, and (2) adopting an evolutionary paradigm for complex systems engineering that involves rapid parallel exploration and a context designed to promote change through competition between design/implementation groups with field testing of multiple variants. The second approach is an extension of many of the increasingly popular variants of systems engineering today.

Scientific document: Systems engineering in an age of complexity (Calvano and John, 2004)

Author(s):

Charles N. Calvano (calvano@nps.navy.mil)

W. E. Meyer

Institute of Systems Engineering, 777 Dyer Road, Naval Postgraduate School, Monterey, CA 93943

Philip John

Centre for Systems Engineering, Cranfield University, Royal Military College of Science, Shrivenham, Swindon, SN6 8LA, United Kingdom

From the document:

This paper considers the creation of Complex Engineered Systems (CESs) and the Systems Engineering approach by which they are designed. The changing nature of the challenges facing Systems Engineering is discussed, with particular focus on the increasing complexity of modern systems. It is argued that modern complexity poses a major challenge to our ability to achieve successful systems and that this complexity must be understood, predicted and measured if we are

to engineer systems confidently. We acknowledge previous work which concluded that, in complex systems, failures ("accidents") may be inevitable and unavoidable. To further explore potential tools for increasing our confidence in complex systems, we review research in the field of Complexity Theory to seek potentially useful approaches and measures and find ourselves particularly interested in the potential usefulness of relationships between the magnitudes of events and their frequency of occurrence. Complexity Theory is found to have characterized naturally occurring systems and to potentially be the source of profitable application to the systems engineering challenge, viz., the creation of complex engineered systems. We are left with the tentative conclusion that truly complex systems, with our present understanding of complex behavior, cannot be designed with a degree of confidence that is acceptable given our current expectations. We recommend that the discipline of systems engineering must investigate this issue as a matter of priority and urgency and seek to develop approaches to respond to the challenge.

<u>Scientific document</u>: Spiral Acquisition of Software-Intensive Systems of Systems (Boehm et al., 2004)

Author(s):

Dr. Barry Boehm

University of Southern California, A. Winsor Brown, University of Southern California, Dr. Victor Basili, University of Maryland, Dr. Richard Turner, George Washington University and OSD/Software-Intensive Systems

From the document:

The Department of Defense and other organizations are finding that the acquisition and evolution of complex systems of systems is both software-intensive and fraught with old and new sources of risk. This article summarizes both old and new sources of risk encountered in acquiring and developing complex software-intensive systems of systems. It shows how these risks can be addressed via risk analysis, risk management planning and control, and application of the risk-driven Win-Win Spiral Model. It will also discuss techniques for handling complicating factors such as compound risks, incremental development, and rapid change, and illustrates the use of principles and practices with experience in applying the model to the U.S. Army Future Combat Systems program and similar programs.

<u>Scientific document</u>: Case Studies of Systems Engineering and Management in Systems Acquisition (Friedman and Sage, 2004)

Author(s):

George Friedman

Department of Industrial and Systems Engineering, University of Southern California, Los Angeles, CA

Andrew P. Sage

Department of Systems Engineering and Operations Research, George Mason University, Fairfax VA, 22030-4444

From the document:

This paper discusses the role of case studies in systems engineering and systems management, especially case studies that involve systems acquisition. We first provide a brief overview of case studies, including some of the analysis techniques useful for the conduct of case studies. Next, we discuss a two-dimensional framework for systems engineering and management case studies. The framework is in the form of a 9 row by 3 column matrix. We present a number of vignettes of case studies, at least one for each of the 27 cellular entries in this matrix. The hope is that this will be a stimulus and precursor of additional systems engineering and management case study efforts, both in terms of appropriate frameworks for these and in the actual conduct of case study research.

Scientific document: Engineering Complex Systems (Norman and Kuras, 2004)

Author(s):

Douglas O. Norman (dnorman@mitre.org)

Michael L. Kuras (mlk@nitre.org)

From the document:

This chapter motivates the need for, and introduces a formal set of processes that constitute the practice of, "Complex Systems Engineering" (CSE). Our experiences and observations strongly suggest Enterprise Engineering is best approached using CSE to engineer and manage the enterprise. Using the current instantiation of the Air and Space Operations Center (AOC2), and the desired evolution of it, the AOC is shown to be best thought of as a complex system. Complex Systems are alive and constantly changing. They respond and interact with their environments—each causing impact on (and inspiring change in) the other. We make the case that a traditional systems engineering (TSE) approach does not scale to the AOC; consequently, we don't believe TSE scales to the "enterprise." We introduce a new set of processes which complement—and do not replace—the processes that constitute traditional systems engineering. The methods for the engineering of complex systems are based on a view of complex systems as having the characteristics of an ecosystem, and the use of processes which take advantage of emergence and which deliberately mimic evolution to accomplish and manage the engineering outcomes desired. The chapter is structured in four major sections:

- *Why Rethink Systems Engineering?*
- *Complexity and Complex Systems*
- *Engineering Complex Systems*
- *Complex Systems Engineering in Practice*

We all must come to grips with the non-deterministic nature of enterprises. We hope to extend the concepts and methods of Systems Engineering to complex systems, and to open up the

professional dialog so as to codify the engineering and management of complex systems and enterprises.

Comments from DRDC reviewer:

This is an important paper for Systems Engineering community as it brings some problems associated with the acquisition of complex systems using traditional engineering approaches. The Complex Systems Engineering (CSE) is introduced as a solution that does not replace traditional processes but complement them. The authors start by defining what is Systems Engineering and by explaining why it should be upgraded. They take the example of Air and Space Operations (AOC) as an example of complex systems to explain where the problems came from and why so many similar engineering projects have failed in the past. The authors then give a description of the difference between systems and complex systems, and how can we measure the complexity of such systems. They then tackle the problem of how complex systems should be engineered. They list some of the needs. DRDC reviewer thinks that their comparison between traditional Systems Engineering and CSE appears to be in error; they do not compare the same things. They then propose some solutions that address some of the listed problems.

Scientific document: The Application of Complexity Theory in the Development if Large Scale ICT Systems (Du Preez and Smith, 2004)

Author(s):

Lukas Johannes duPreez and Abraham Johannes Smith

From the document:

The elements of complexity theory (chaos theory) found application in many diverse disciplines, including the social and management science. It became a means to address some of the vexing problems that could not be solved through causal analysis. Complexity theory contradicts many of the existing views of conventional management and requires a cognitive change from a rational Newtonian paradigm to a non-linear, dynamic and complex systems paradigm. This paper unites the principles of complexity theory with Information and Communication Technologies (ICT) project management by considering any large-scale ICT development project as a non-linear, dynamic and complex system within the context of a larger complex environment. The interactions between the different complex dimensions of the project state are discussed. ICT project- and risk management are described within the context of the elements of complexity theory such as variables, attractors and fractals.

Comments from DRDC reviewer:

This is an important paper for organizations that must deals with the conception and the development of large systems; the conclusions are not only valid for ICT but for any kind of systems. The authors start by making a short but very appropriate literature review on the Complexity Theory and on project failures. They use the concepts of attractor and fractal to describe the four classes of behaviour cellular automata may have. They define attractor and fractal as pattern of behaviours. They then make the distinction between linear and non-linear behaviours of systems and present concepts like interdependence, relationship, holistic view,

initial conditions, effects, edge-of-chaos, emergence, disturbance, bifurcation, state phase and strange attractors. The authors then present an approach to Project Management that is based on presented concepts. They define the world “system” as made of many dimensions (like people, processes, technologies, etc) and they call its environment “ecosystem”. Project Management in complex environment is presented as a system by itself; it is made of many elements that are working together to achieve a common goal or mission. They present what could be a strange attractor in Project Management and what could be the variables defining the dimensions of the system. The effects of variable initial conditions are also discussed. Some high-level system dimensions are then described for the context of the planning phase of a project. These are: interdependence, interaction of systems, intrinsic complexity, sensitive variables, stable attractors, strange attractors, fractal structure, processes and risk planning. They then propose some guidelines to manage the project state space during its execution phase.

<u>Scientific document</u>: Process modeling: A systems engineering tool for analyzing complex systems (Osmundson et al., 2004)

Author(s):

John S. Osmundson, Russell Gottfried, Chee Yang Kum, Lau Hui Boon, Lim Wei Lian, Poh Seng Wee Patrick, Tan Choo Thye

From the document:

This paper presents a method for performing architectural analyses of complex systems-of-systems using process modeling. A process is a series of actions undertaken by a system-of-systems to produce one or more end results, typically products and services. The method applies to systems-of systems whose effectiveness and performance depend strongly on process timelines, such as distributed information systems, logistics systems, and manufacturing and distribution systems. A fundamental tool in this method is the development of a unified modeling language (UML) related view of the system-of-system processes of interest and the subsequent conversion of the UML related view into an end-to-end system-of-systems executable object-oriented simulation model. This method is illustrated by applying process modeling and simulation to analysis of a military systems-of-systems, an expeditionary warfare system envisioned for the 2015-2020 time frame. Expeditionary warfare is the operation of an armed force in an area far from a supportable home base and supported by temporarily established means. The U.S. military has conducted expeditionary warfare in the past by building up forces, equipment, and supplies at a beachhead before moving on to an objective. There is current interest in the U.S. military to shift from the concept of establishing a beachhead and then movement to an objective to a concept of sea-based launching and supporting forces and sea-to-objective maneuver for fighting forces. A fundamental tool in this analysis is an end-to-end object-oriented simulation model emulating the full implementation of these force architectures and design factors as well as accounting for the impact of varying levels of operational intensity, attrition of personnel and transport vehicles, weather, mining sea lanes, transport vehicle operating and availability constraints, landing spot constraints, and transit and communications delays. This paper focuses on the framework of the simulation model and its most significant findings as applied to expeditionary warfare concepts as an example of the application of process modeling to architectural analyses of complex systems-of-systems.

<u>Scientific document</u>: Characterizing Complex Product Architectures (Sharman and Yassine, 2004)

Author(s):

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Massachusetts Institute of Technology, Cambridge, MA 02139

Ali A. Yassine

Department of General Engineering, University of Illinois at Urbana-Champaign, 117 Transportation Building, Urbana, IL 61801

From the document:

Due to the large-scale nature of complex product architectures, it is necessary to develop some form of abstraction in order to be able to describe and grasp the structure of the product, facilitating product modularization. In this paper we develop three methods for describing product architectures: (a) the Dependency Structure Matrix (DSM), (b) Molecular Diagrams (MD), and (c) Visibility-Dependency (VD) signature diagrams. Each method has its own language (and abstraction), which can be used to qualitatively or quantitatively characterize any given architecture spanning the modular-integrated continuum. A consequence of abstraction is the loss of some detail. So, it is important to choose the correct method (and resolution) to characterize the architecture in order to retain the salient details. The proposed methods are suited for describing architectures of varying levels of complexity and detail. The three methods are demonstrated using a sequence of illustrative simple examples and a case-study analysis of a complex product architecture for an industrial gas turbine.

<u>Scientific document</u>: A Highly-optimized Tolerance (Hot)-inspired Model of the Large Scale Systems Engineering Process (Wojcik, 2004)

Author(s):

Leonard A. Wojcik

Center for Advanced Aviation System Development (CAASD), The MITRE Corporation, Mclean, VA 22102 U.S.

From the document:

Large-scale systems engineering efforts involving multiple stakeholders often have been problematic, and there has been recent interest in understanding how to improve the systems engineering process. This paper presents an approach to modeling the systems engineering process, with possible extensions to systems investment and systems operations, inspired by the highly optimized tolerance (HOT) framework for understanding complexity in designed systems. HOT is complementary to agent-based modeling (ABM) in the sense that it emphasizes the centrally planned aspect of designed systems with tradeoffs and uncertainty, rather than

distributed decision making based on local knowledge and goals. To begin the exploration of models of the systems engineering process, a temporal model is presented with stakeholder interactions modeled as random events. Following the HOT approach, planning behavior is framed as stochastic optimization, which is reduced to a open-loop control problem. The initial results suggest promise for the HOT-inspired framework in helping to understand how to improve the systems engineering process, but more exploratory work is needed, including work on relating actual systems engineering experience to the models.

Scientific document: Process modeling: A systems engineering tool for analyzing complex systems (Osmundson et al., 2004)

Author(s):

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Republic of Singapore Navy, Republic of Singapore

Tan Choo Thye

Singapore Armed Forces, Republic of Singapore

From the document:

This paper presents a method for performing architectural analyses of complex systems-of-systems using process modeling. A process is a series of actions undertaken by a system-of-systems to produce one or more end results, typically products and services. The method applies to systems-of systems whose effectiveness and performance depend strongly on process timelines,

such as distributed information systems, logistics systems, and manufacturing and distribution systems. A fundamental tool in this method is the development of a unified modeling language (UML) related view of the system-of-system processes of interest and the subsequent conversion of the UML related view into an end-to-end system-of-systems executable object-oriented simulation model. This method is illustrated by applying process modeling and simulation to analysis of a military systems-of-systems, an expeditionary warfare system envisioned for the 2015–2020 time frame. Expeditionary warfare is the operation of an armed force in an area far from a supportable home base and supported by temporarily established means. The U.S. military has conducted expeditionary warfare in the past by building up forces, equipment, and supplies at a beachhead before moving on to an objective. There is current interest in the U.S. military to shift from the concept of establishing a beachhead and then movement to an objective to a concept of sea-based launching and supporting forces and sea-to-objective maneuver for fighting forces. A fundamental tool in this analysis is an end-to-end object-oriented simulation model emulating the full implementation of these force architectures and design factors as well as accounting for the impact of varying levels of operational intensity, attrition of personnel and transport vehicles, weather, mining sea lanes, transport vehicle operating and availability constraints, landing spot constraints, and transit and communications delays. This paper focuses on the framework of the simulation model and its most significant findings as applied to expeditionary warfare concepts as an example of the application of process modeling to architectural analyses of complex systems-of-systems.

<u>Scientific document</u>: Engineering Self-Organizing Referral Networks for Trustworthy Service Selection (Pınar and Singh, 2005)

Author(s):

Pınar Yolum and Munindar P. Singh

From the document:

Developing, maintaining, and disseminating trust in open, dynamic environments is crucial.We propose self-organizing referral networks as a means for establishing trust in such environments. A referral network consists of autonomous agents that model others in terms of their trustworthiness and disseminate information on others' trustworthiness. An agent may request a service from another; a requested agent may provide the requested service or give a referral to someone else. Possibly with its user's help, each agent can judge the quality of service obtained. Importantly, the agents autonomously and adaptively decide with whom to interact and choose what referrals to issue, if any. The choices of the agents lead to the evolution of the referral network, whereby the agents move closer to those that they trust. This paper studies the guidelines for engineering self-organizing referral networks. To do so, it investigates properties of referral networks via simulation. By controlling the actions of the agents appropriately, different referral networks can be generated. This paper first shows how the exchange of referrals affects service selection. It identifies interesting network topologies and shows under which conditions these topologies emerge. Based on the link structure of the network, some agents can be identified as authorities. Finally, the paper shows how and when such authorities emerge. The observations of these simulations are then formulated into design recommendations that can be used to develop robust, self-organizing referral networks.

Scientific document: A General Methodology for Designing Self-Organizing Systems (Gershenson, 2005a)

Author(s):

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http://homepages.vub.ac.be/˜cgershen

From the document:

Our technologies complexify our environments. Thus, new technologies need to deal with more and more complexity. Several efforts have been made to deal with this complexity using the concept of self-organization. However, in order to promote its use and understanding, we must first have a pragmatic understanding of complexity and self-organization. This paper presents a conceptual framework for speaking about self-organizing systems. The aim is to provide a methodology useful for designing and controlling systems developed to solve complex problems. First, practical notions of complexity and self-organization are given. Then, starting from the agent metaphor, a conceptual framework is presented. This provides formal ways of speaking about "satisfaction" of elements and systems. The main premise of the methodology claims that reducing the "friction" or "interference" of interactions between elements of a system will result in a higher "satisfaction" of the system, i.e. better performance. The methodology discusses different ways in which this can be achieved. A case study on self-organizing traffic lights illustrates the ideas presented in the paper.

Comments from DRDC reviewer:

The author presents an interesting mathematical language for expressing concepts related to complex systems. Care should be taken if one wants to re-use equations from this paper because they do not necessarily apply to all types of complex systems. The author presents a methodology made of five steps to conceive complex systems. Many important concepts are discussed in this paper. Simulation is then used to test the methodology and ways of modelling into a concrete case study.

Scientific document: Practical Applications of Complexity Theory for Systems Engineers (Sheard, 2005)

Author(s):

Sarah A. Sheard (sheard@systemsandsoftware.org)

Systems and Software Consortium, Inc., 2214 Rock Hill Rd. Herndon, Virginia 20170

From the document:

This paper provides a basic background in chaos and complexity theory and shows systems engineers how to improve the way they work in accordance with their increased awareness of the

complex nature of systems, enterprises, and the environment. As systems and the enterprises in which they are developed become increasingly complex, systems engineering as learned and taught in the twentieth century should be supplemented by principles learned in the new sciences of complexity and chaos. Awareness of complexity theory can help practicing engineers perform their tasks differently on projects, in ways ranging from understanding the problem space and making models of the environment early in the life cycle, through managing changing requirements, designing differently, and identifying and managing risks, to supporting changing project management approaches.

In addition, a science of complex systems engineering is being formed. This involves developing a formal theoretical backdrop for the heuristics that systems engineers have experientially found effective in architecting and developing complex systems. Complexity theory is enriching efforts to develop this advanced system engineering approach and practices.

Comments from DRDC reviewer:

This is an important paper for the Systems Engineering community as it introduces some important aspects of the Complexity Theory and of chaos for the context of Systems Engineering. The author briefly explains the different states within which a system or a project can evolve. This spectrum of states contains three "regions" ranging from "highly controlled systems", to "less controlled systems" to "not controlled systems". She explains that the optimal region for a system to operate in is the middle; the "Edge-of-Chaos"; *At the edge of chaos, systems are best poised to take in information from the outside world and change themselves to react to it, increasing their own fitness faster than competing systems*. Listing the different roles in Systems Engineering, she proposes improvements to currents approaches. *The utility of complexity theory is that it gives an alternative way to look at complex systems and systems-of-systems, both to understand their behaviour and to predict risks and outcomes under a variety of circumstances*. (…) *strategic planners need to move from Mechanics of parts to Dynamics of the whole, from Separateness to Relatedness, from Organizational charts as truth, and indicator of entitlements and bureaucracy, to Organizational charts as a guide to centers of core activity, sources of energy, and innovation, from Controlling, stabilizing, or managing change to Responding to and influencing change as it is emerging.*

<u>Scientific document</u>: 2nd Workshop on Complexity in Design and Engineering (Johnson, 2005)

Author(s):

Chris Johnson (Editor)

Department of Computing Science, University of Glasgow, Scotland.

From DRDC reviewer:

This report contains the presented scientific papers of this workshop. The following lines list these papers.

- *WHAT ARE EMERGENT PROPERTIES AND HOW DO THEY AFFECT THE ENGINEERING OF COMPLEX SYSTEMS? (CHRIS .W. JOHNSON)*

- *ABSTRACTING COMPLEXITY FOR DESIGN PLANNING (DAVID WYNN, CLAUDIA ECKERT AND P JOHN CLARKSON)*
- *DESIGN CHANGE AND COMPLEXITY (CHRIS EARL, CLAUDIA ECKERT, JOHN CLARKSON)*
- *CREATIVITY IN THE DESIGN OF COMPLEX SYSTEMS (NEIL MAIDEN & SARA JONES)*
- *DIVERSITY AS A DETERMINANT OF SYSTEM COMPLEXITY (BRIAN SHERWOOD JONES, PAUL ANDERSON)*
- *DESIGN OF THE ICT INFRASTRUCTURE OF AN EDUCATIONAL SYSTEM (PEDRO BAQUERO, ROSA MARÍA AGUILAR, ALEJANDRO AYALA)*
- *COMPLEXITY OF DESIGN IN SAFETY CRITICAL INTERACTIVE SYSTEMS: (SANDRA BASNYAT, DAVID NAVARRE, PHILIPPE PALANQUE)*
- *UNCOVERING THE INFORMATION NEEDS IN COMPLEX AEROSPACE SYSTEMS (IYA SOLODILOVA AND PETER JOHNSON)*
- *VALIDATING A PROCESS FOR UNDERSTANDING HUMAN ERROR PROBABILITIES IN COMPLEX HUMAN COMPUTER INTERFACES (RICHARD MAGUIRE)*
- *THE DESIGN OF COMPLETE SYSTEMS: DEVELOPING HUMAN FACTORS GUIDANCE FOR COTS ACQUISITION (ANNE BRUSEBERG)*
- *SOURCES OF COMPLEXITY IN THE DESIGN OF HEALTHCARE SYSTEMS: AUTONOMY VS. GOVERNANCE (A. TALEB-BENDIAB, DAVID ENGLAND, MARTIN RANDLES, PHIL MISELDINE, KAREN MURPHY)*
- *AUTOMATION, INTERACTION, COMPLEXITY, AND FAILURE: A CASE STUDY (ROBERT L WEARS, MD, MS AND RICHARD I. COOK, MD)*
- *WHAT MAKES EMERGENCY AMBULANCE COMMAND AND CONTROL COMPLEX? (B.L. WILLIAM WONG, JARED HAYES, TONY MOORE)*
- *V2: USING VIOLATION AND VULNERABILITY ANALYSIS TO UNDERSTAND THE ROOT-CAUSES OF COMPLEX SECURITY INCIDENTS (CHRIS. W. JOHNSON)*
- *COMPLEXITIES OF MULTI-ORGANISATIONAL ERROR MANAGEMENT (JOHN DOBSON, SIMON LOCK, DAVID MARTIN)*
- *CAPTURING EMERGING COMPLEX INTERACTIONS - SAFETY ANALYSIS IN ATM (MASSIMO FELICI)*
- *EXTENDING SMALL GROUP THEORY FOR ANALYSING COMPLEX SYSTEMS (ALISTAIR SUTCLIFFE)*
- *A SYSTEMS APPROACH TO RESOLVING COMPLEX ISSUES IN A DESIGN PROCESS (EMAD MARASHI, JOHN P. DAVIS)*
- *A COMMUNICATION TOOL BETWEEN DESIGNERS AND ACCIDENTOLOGISTS FOR THE DEVELOPMENT OF SAFETY SYSTEMS (WALID BEN AHMED, MOUNIB MEKHILEF, MICHEL BIGAND, YVES PAGE)*

- *A BARRIER-BASED APPROACH TO INTEGRATING HUMAN FACTORS ANALYSIS INTO THE ANALYSIS AND DESIGN OF COMPLEX SYSTEMS (B. SCHUPP, P. WRIGHT., M. HARRISON)*
- *ADAPTING INTERFACE REPRESENTATIONS FOR MOBILE SUPPORT IN INTERACTIVE SAFETY CRITICAL CONTEXTS (FABIO PATERNÒ, CARMEN SANTORO, DAVID TOUZET)*
- *VIEWPOINTS AND VIEWS IN ENGINEERING CHANGE MANAGEMENT (RENÉ KELLER, CLAUDIA M. ECKERT, P. JOHN CLARKSON)*
- *APPLYING TASK ANALYSIS TO FACILITATE THE DESIGN OF CONTEXT-AWARE TECHNOLOGIES (YUN-MAW CHENG AND CHRIS JOHNSON)*

Scientific document: On Engineering and Emergence (Fromm, 2006)

Author(s):

Jochen Fromm (fromm@vs.uni-kassel.de)

Distributed Systems Group, Kassel University, EECS Department for Electrical Engineering and Computer Science, Wilhelmshöher Allee 73, D-34121 Kassel, Germany

(http://www.vs.uni-kassel.de/~fromm/)

From the document:

The engineering and design of self-organizing systems with emergent properties is a long-standing problem in the field of complex and distributed systems, for example in the engineering of self-organizing Multi-Agent Systems. The problem of combining engineering with emergence - to find a simple rule for a complex pattern - equals the problem of science in general. Therefore the answers are similar, and the scientific method is the general solution to the problem of engineering complex systems.

Journal: A Complex Systems Perspective on Concurrent Engineering (Special Issue)

Can be found at the following address or web site (2006):

CERA Journal Special Issue.

http://necsi.org/postdocs/sayama/ceraj2.html

http://www.ceraj.com/

From the web site:

Why can concurrent engineering projects take so long and cost so much, despite our best efforts to use such apparently sensible techniques as multi-functional design teams, set-based design, and computer-aided collaborative design tools? Consider for example the Boeing 767-F redesign program. Some conflicts were not detected until long (days to months) after they had occurred,

resulting in wasted design time, design rework, and often even scrapped tools and parts. It was estimated that roughly half of the labor budget was consumed dealing with changes and rework, and that roughly 25-30% of design decisions had to be re-worked. Since maintaining scheduled commitments was a priority, design rework often had to be done on a short flow-time basis that typically cost much more (estimates ranged as high as 50 times more) and sometimes resulted in reduced product quality. Conflict cascades that required as many as 15 iterations to finally produce a consistent design were not uncommon for some kinds of design changes. All this in the context of Boeing's industry-leading concurrent engineering practices. The dynamics of current collaborative design processes are thus daunting, and have led to reduced design quality, long design cycles, and needlessly high costs. The emerging discipline of complex systems research offers a new and potentially powerful perspective on these problems, by attempting to understand the dynamics of distributed systems using such concepts as chaos, power laws, self-similarity, emergence, self-organization, networks, adaptation, evolution, and so on. It has proven to be quite fruitful, offering powerful and intriguing explanations and prescriptions for phenomena ranging from vehicle traffic to global economies to evolution to the weather. This special issue collects five papers that apply the complex systems perspective to concurrent engineering. The papers by Klein et al., Ford et al. Loch et al. and Yassine et al. describe how we can use complex systems models to help understand and improve the emergent dynamics of concurrent engineering processes. The paper by Wallace et al. describes the kind of novel computing infrastructure that becomes necessary when supporting emergent concurrent engineering processes.

Contributors:

- Mark Klein, Hiroki Sayama, Peyman Faratin and Yaneer Bar-Yam: The Dynamics of Collaborative Design: Insights From Complex Systems and Negotiation Research
- David N. Ford and John D. Sterman: Iteration Management for Reduced Cycle Time in Concurrent Development Projects
- Christoph Loch, Jürgen Mihm and Arnd Huchsermeier: Concurrent Engineering and Design Oscillations in Complex Engineering Projects
- Ali Yassine and Dan Braha: Complex Concurrent Engineering and the Design Structure Matrix Method
- David Wallace, Elaine Yang and Nicola Senin: Integrated Simulation and Design Synthesis

<u>Tutorial</u>: A complete Picture to Model Complex Systems: What, When, How and Why Model Systems (Faisandier et al., 2005)

Author(s):

Alain Faisandier, Claude Feliot and Jean-Philippe Lerat

Comments from DRDC reviewer:

DRDC reviewer attended this tutorial at the 15th Annual International INCOSE Symposium. The hard copy of the presentation may be obtained with the permission of authors. The tutorial presents an overview of the traditional Systems Engineering with emphasis on modeling complex

systems. The Systems Engineering and Architecting parts of their presentation are basic and useful. They bring many important concepts that are useful when dealing with complex systems. Their template matrix for integrating models and system consistency rules (the Semantic Network) is not clear. It was the subject of many questions and argumentation. The choice of basis of the matrix appears to be deficient, incomplete and not orthogonal.

Book: General Principles of Systems Design (Weinberg and Weinberg, 1988)

Author(s):

Gerald M. Weinberg and Daniela Weinberg

Book: The Art of Systems Architecting, Second Edition (Maier and Rechtin, 2002)

Author(s):

Mark W. Maier and Eberhardt Rechtin

From Amazon.com

Contents include extending the architecture paradigm, heuristics as tools, manufacturing systems, social systems, software and information technology systems, collaborative systems, design progression in system architecting, integrated modeling methodologies, architecture frameworks, and more. "…The only way to develop this skill is to serve an apprenticeship with a proven practitioner. However, there are simply not enough gurus to go around, and I would recommend this book both for students of the discipline and as serious reading for experienced designers who wish to recognize and maintain their expertise." -E. James in Computing Millieux

Book: Advanced Systems Thinking, Engineering, and Management (Hitchins, 2003)

Author(s):

Derek K. Hitchins

From Amazon.com

Text offers a comprehensive understanding of systems ideas and methods. Introduces a generic systems life-cycle theory that helps readers understand how systems form, persist, and decay.

Comments from DRDC reviewer:

This book is often cited in the scientific literature.

3.10.15 Cellular Automata

Book: Cellular Automata and Complexity: Collected Papers by Stephen Wolfram (Wolfram, 2002)

Author(s):

Stephen Wolfram (sw-staff@wolfram.com)

(http://www.stephenwolfram.com)

From Amazon.com

These original papers on cellular automata and complexity, some of which are widely known in the scientific community, provide a highly readable account of what has become a major new field of science, with important implications for physics, biology, economics, computer science, and many other areas. Collected papers from Wolfram's original papers on cellular automata and complexity. Provides a highly readable account of what has become a major new field of science. Paper. DLC: Cellular automata.

From Stephen Wolfram web site ()

Are mathematical equations the best way to model nature? For many years it had been assumed that they were. But in the early 1980s, Stephen Wolfram made the radical proposal that one should instead build models that are based directly on simple computer programs. Wolfram made a detailed study of a class of such models known as cellular automata, and discovered a remarkable fact: that even when the underlying rules are very simple, the behavior they produce can be highly complex, and can mimic many features of what we see in nature. And based on this result, Wolfram began a program to develop what has become A New Kind of Science. The results of Wolfram's work found many applications, from the so-called Wolfram Classification central to fields such as artificial life, to new ideas about cryptography and fluid dynamics. This book is a collection of Wolfram's original papers on cellular automata and complexity. Some of these papers are widely known in the scientific community; others have never been published before. Together, the papers provide a highly readable account of what has become a major new field of science, with important implications for physics, biology, economics, computer science and many other areas.

Web site: Cellular Automata (a description)

Web site addresses:

http://en.wikipedia.org/wiki/Cellular_automaton

Web site: Logistic map (a description)

Web site addresses:

http://en.wikipedia.org/wiki/Logistic_map

Web site: Julia set (a description)

Web site addresses:

http://en.wikipedia.org/wiki/Julia_set

Web site: Lorenz attractor (a description)

Web site addresses:

http://en.wikipedia.org/wiki/Lorenz_attractor

4 Experts

<u>Expert</u>: Axelrod, Robert

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http://www-personal.umich.edu/~axe/

From the web site:

Robert Axelrod is the Arthur W. Bromage Distinguished University Professor of Political Science and Public Policy at the University of Michigan. He has appointments in the Department of Political Science and the Gerald R. Ford School of Public Policy. Prior to coming to Michigan he taught at the University of California, Berkeley (1968-74). He holds a BA in mathematics from the University of Chicago (1964), and a PhD in political science from Yale (1969). He is best known for his interdisciplinary work on the evolution of cooperation which has been cited in more than five hundred books and four thousand articles. His current research interests include complexity theory (especially agent-based modeling), and international security. Among his honors and awards are membership in the National Academy of Sciences, a five year MacArthur Prize Fellowship, the Newcomb Cleveland Prize of the American Association for the Advancement of Sciences for an outstanding contribution to science, and the National Academy of Sciences Award for Behavioral Research Relevant to the Prevention of Nuclear War. Recently Axelrod has consulted and lectured on promoting cooperation and harnessing complexity for the United Nations, the World Bank, the U.S. Department of Defense, and various organizations serving health care professionals, business leaders, and K-12 educators.

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http://necsi.org/faculty/bar-yam.html

From the web site:

Professor Bar-Yam is interested in the unified properties of complex systems as a systematic strategy for answering basic questions about the world. His research is focused both on formalizing complex systems concepts and relating them to everyday problems. In particular, he is interested in the relationship between observations at different scales, formal properties of descriptions of systems, the relationship of structure and function, the representation of information as a physical quantity, and quantitative properties of the complexity of real systems. Applications have been to physical, biological and social systems. Leading up to his interest in complex systems he worked on the properties of defects in semiconductors, amorphous materials, surfaces and material growth, polymer dynamics, and neural networks.

Expert: Burgess, Guy

Address(es):

http://conflict.colorado.edu/burgess.html

From the web site:

Guy Burgess is a Founder and Co-Director of the University of Colorado Conflict Research Consortium. He holds a Ph.D in Sociology and has been working in the conflict resolution field, as a scholar and a practitioner, since 1979. His primary interests involve the study and management of intractable conflicts, public policy dispute resolution, and the dissemination of conflict resolution knowledge over the Internet. He is one of the primary authors and creators of the Online Training Program on Intractable Conflicts, a "precursor" to the proposed project, and is the Co-Director of the CRInfo Project the Conflict Resolution Information Source (http://www.crinfo.org). Dr. Burgess has edited and authored a number of books and articles, the most recent being The Encyclopedia of Conflict Resolution (with Heidi Burgess, ABC-Clio 1999).

Expert: Cook, Stephen (Canadian Expert)

Address(es):

sacook@cs.toronto.edu

10 King's College Road, Sandford Fleming Building, Room SF2303C, University of Toronto, Toronto, Ontario M5S 3G4, Phone (416)-978-5183, Fax (416) 978-1931

http://www.cs.toronto.edu/~sacook/

http://www.cs.toronto.edu/DCS/People/Faculty/sacook.html

From the web site:

Stephen Cook was born in Buffalo, New York, received his BSc degree from University of Michigan in 1961, and his S.M. and PhD degrees from Harvard University in 1962 and 1966 respectively. From 1966 to 1970 he was Assistant Professor, University of California, Berkeley. He joined the faculty at the University of Toronto in 1970 as an Associate Professor, and was promoted to Professor in 1975 and University Professor in 1985. His principal research areas

are computational complexity and proof complexity, with excursions into programming language semantics and parallel computation. He is the author of over 60 research papers, including his famous 1971 paper "The Complexity of Theorem Proving Procedures" which introduced the theory of NP completeness and proved that the Boolean satisfiability problem is NP complete. He is the 1982 recipient of the Turing award, and was awarded a Steacie Fellowship in 1977,a Killam Research Fellowship in 1982, and received the CRM/Fields Institute Prize in 1999. He received Computer Science teaching awards in 1989 and 1995. He is a fellow of the Royal Society of London, Royal Society of Canada, and was elected to membership in the National Academy of Sciences (United States) and the American Academy of Arts and Sciences. Twenty-six students have completed their PhD degrees under his supervision, and many of them now have prominent academic careers of their own.

Expert: De Rosnay, Joël

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http://necsi.org/faculty/bar-yam.html

http://csiweb2.cite-sciences.fr/derosnay/

From the web site:

Joël de Rosnay, Docteur ès Sciences, est Président exécutif de Biotics International et Conseiller du Président de la Cité des Sciences et de l'Industrie de la Villette dont il a été le Directeur de la Prospective et de l'Evaluation jusqu'en juillet 2002 . Entre 1975 et 1984, il a été Directeur des Applications de la Recherche à l'Institut Pasteur. Ancien chercheur et enseignant au Massachusetts Institute of Technology (MIT) dans le domaine de la biologie et de l'informatique, il a été successivement Attaché Scientifique auprès de l'Ambassade de France aux Etats-Unis et Directeur Scientifique à la Société Européenne pour le Développement des Entreprises (société de "Venture capital"). Il s'intéresse particulièrement aux technologies avancées et aux applications de la théorie des systèmes. Auteur de : "Le Macroscope" (1975, Prix de l'Académie des Sciences Morales et Politiques), "les Chemins de la Vie" (1983), "le Cerveau Planétaire" (1986), et de plusieurs rapports, notamment: "Biotechnologies et Bio-Industrie (1979), annexe au Rapport "Sciences de la Vie et Société" des Professeurs Gros, Jacob et Royer, ainsi que le rapport ayant conduit à la création du CESTA (Centre d'Etudes des Systèmes et des Technologies Avancées, 1982). Il a été chroniqueur scientifique à Europe1 de 1987 à 1995 et auteur de plusieurs ouvrages scientifiques destinés à un large public, dont "Les origines de la vie" (1965), "La Malbouffe" (1979), "La révolution biologique" (1982), "Branchez-vous" (Grand Prix de la littérature Micro-informatique Grand Public 1985), "l'Aventure du vivant" (1988), "L'avenir en direct" (1989). "Les Rendez-vous du Futur" (1991). "L'homme symbiotique, regards sur le troisième millénaire", Seuil, 1995. "La plus belle histoire du monde", avec Yves Coppens, Hubert Reeves, et Dominique Simonnet, Seuil, 1996. "Une vie en plus, la longévité pourquoi faire ?" avec Jean-Louis, Servan-Schreiber, François de Closets et Dominique Simonnet, Seuil, 2005. Joël de

Rosnay est lauréat du Prix de l'Information Scientifique 1990 de l'Académie des Sciences et du prix Benjamin Constant des Arts de la Communication 1994 de la Société d'Encouragement de l'Industrie Nationale.

Expert: Doneri, Don (Canadian Expert)

Address(es):

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http://www.hfn.ca/Donderi.html

From the web site:

Principal Consultant at Human Factors North Inc. and Associate Professor of Psychology at McGill University. Dr. Donderi has over 40 years experience in human factors / ergonomics and applied experimental psychology. He began his applied career in the late 1950's, working for the IBM Federal Systems Division in Owego, N.Y. He is the co-author of a psychology textbook, many research papers and technical reports on human perception, motivation, memory and thinking. He has designed and programmed computer interfaces for military human factors/ergonomics applications, and has designed interfaces for telemarketing applications. He is an expert in human perception and perceptual judgment, and consults regularly with the Canadian pulp and paper industry on the development of better consumer paper products. He has appeared as an expert witness in criminal and civil cases involving human perception and performance. Dr. Donderi has managed large-scale field studies on human performance in marine and Arctic marine environments, and has consulted extensively on the human factors aspects of nuclear power plant operations. Professional Competence: Analysis, expert testimony and research in the field of general experimental psychology including learning, perception, cognition, and motivation. Industrial processes and other tasks involving visual search and visually-guided behaviour. Design of workstations and workplaces; computer interfaces, visual displays and marine ergonomics (wheelhouses, accommodations, engine spaces). Cognitive and perceptual aspects of systems design, operation and maintenance including task analysis, shift schedules and control room layout.

Expert: Edmonds, Bruce

Address(es):

bruce@edmonds.name

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Centre for Policy Modelling, Manchester Metropolitan University Business School, Aytoun Building, Aytoun Street, Manchester M1 3GH, United Kingdom.

http://bruce.edmonds.name/

From the web site:

Mr Edmonds is a Senior Research Fellow (equivalent to a Reader) of the Centre for Policy Modelling; A Research Associate of the Macaulay Institute; On the editorial Boards of: Interaction Studies; Entropy; and the Journal of Artificial Societies and Social Simulation; The publications officer for the European Social Simulation Association; The director of studies for the following PhD students: Olivier Barthelemy, Rodolfo De Sousa and Luis Izquierdo; A Supervisor for the following PhD students: Bogdan Werth and Shah Alam; The Principal investigator for the MMU part of the NANIA project (an EPSRC Novel Computation project); A co-investigator on the CAVES, and NEWATER projects (EU 6FP projects); A member/node of the following EU networks: AgentLink III, GIACS and EXYSTENCE.

Expert: Edmonds, Jeff (Canadian Expert)

Address(es):

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Theory Group, Department of Computer Science & Engineering, York University, CSB Building, room 3044, Phone: (416) 736-2100 ext. 33295, Home: (416) 538-7413.

http://www.cs.yorku.ca/~jeff/

Expert: Flake, Garry William

Address(es):

http://flakenstein.net/

From the web site:

Dr. Flake is a Technical Fellow at Microsoft, where he is responsible for bridging Microsoft Research and MSN, and for setting the technology vision and future direction of the MSN portal, web search, desktop search and commercial search efforts. He is also the founder and director of Live Labs, which represents Microsoft's greatest investment in applied research focused on Internet technologies. Prior to joining Microsoft, Dr. Flake founded Yahoo! Research Labs, ran Yahoo!s corporate R&D activities and company-wide innovation effort, and was Overture's Chief Science Officer. Before joining Overture, he was a research scientist at NEC Research Institute and the leader of its Web data-mining program. He has numerous publications spanning over 15 years which have focused on machine learning, data mining, and self-organization. His other research interests include Web measurements, efficient algorithms, models of adaptation inspired by nature, and time series forecasting. Dr. Flake has served on numerous academic conference and workshop organization committees and is a member of the editorial board for the Association for Computing Machinery's Transactions on Internet Technologies. Dr. Flake, who earned his Ph.D. in computer science from the University of Maryland, also wrote the award-winning book, The Computational Beauty of Nature, which is used in college courses worldwide.

Expert: Gell-Mann, Murray

Address(es):

1399 Hyde Park Road, Santa Fe, NM 87501-8943, 505-984-8800, 505-982-0565 (fax).

http://www.santafe.edu/~mgm/

http://www.santafe.edu/sfi/People/mgm/

http://www.santafe.edu/sfi/People/mgm/mgmbio.html

From (Chan, 2001):

Murray Gell-Mann is Co-Chairman of the Science Board of the Santa Fe Institute and author of the popular science book The Quark and the Jaguar: Adventures in the Simple and the Complex. He was the Nobel laureate in physics in 1969 for his work on the theory of elementary particles. He currently focuses on complex adaptive systems.

Expert: Gershenson, Carlos

Address(es):

cgershen@vub.ac.be

Centrum Leo Apostel, Vrije Universiteit Brussel, Krijgskundestraat 33, Brussels, 1160, Belgium.

http://www.vub.ac.be/CLEA

http://homepages.vub.ac.be/~cgershen/

From the web site:

Mister Gershenson have a wide variety of academic interests, including self-organizing systems, artificial life, evolution, complexity, cognition, artificial societies, and philosophy. I am also Contributing Editor for Complexity Digest, Book Review Editor of Artificial Life, and webmaster of alife.org. He is also co-steering the Brussels Complexity site (which is at an early stage).

Expert: Goodwin, Brian

Address(es):

http://www.edge.org/3rd_culture/bios/goodwin.html

http://www.edge.org/3rd_culture/goodwin/goodwin_p1.html

From (Chan, 2001):

Brian Goodwin is a professor of biology in England and a member of the Board of Directors at the Santa Fe Institute. His work has been in 'new' biology – biology, in the form of an exact science, of complex systems dealing with dynamics and emergent order.

<u>Expert</u>: Heylighen, Francis

<u>Address(es):</u>

http://pespmc1.vub.ac.be/HEYL.html

From Web site:

Professor Heylighen describes himself: *I am a research professor at the Free University of Brussels (VUB), and director of the transdisciplinary research group on "Evolution, Complexity and Cognition". I am also affiliated to the Center "Leo Apostel" and the Department of Philosophy. I am also an editor of the Principia Cybernetica Project, an international organization for the collaborative development of an evolutionary-systemic philosophy. The main focus of my research is the evolution of complexity: how do higher levels of organization originate (metasystem transitions) and develop? I have worked in particular on the development of knowledge and intelligence, and its application to the emerging intelligent web, or "global brain". I use this evolutionary-cybernetic approach as a framework for the integration of ideas from different disciplines into an encompassing "world view". I have largely finished the draft for a popular science book presenting this evolutionary world view to a broad audience, and am looking for agents or publishers interested in this project. I also teach an introductory course (in Dutch) on this topic at the VUB, and have several PhD students working on related subjects. This broad evolutionary view, together with its practical applications on advanced web systems, has given me a growing reputation as a visionary thinker on the future of the information society.*

As a true interdisciplinarian, I have moreover done research and published papers about various subjects in various scientific disciplines, from mathematical physics, and computer support systems to humanistic psychology, including the following:

- *Collective Intelligence, and the global brain*
- *Social Progress and the measurement of Happiness (with Jan Bernheim)*
- *Algorithms for Learning Webs (with Johan Bollen)*
- *Foundations of Cybernetics and Systems Theory (with Cliff Joslyn and Valentin Turchin)*
- *Evolutionary Development of Social Systems (with the famous methodologist Donald T. Campbell)*
- *Memetics or mechanisms for cultural evolution*
- *Formality/context-dependence in Linguistics (with Jean-Marc Dewaele)*
- *Psychology of Causal Attributions (with Frank Van Overwalle)*
- *Maslow's theory of the Self-Actualizing Personality*
- *Bootstrapping Knowledge Representations*
- *Foundations of Quantum Mechanics and of Space-Time Structure (see also my PhD. Thesis)*

- *Gifted people and their problems (for those who recognize themselves in these traits)*

Check my list of publications for more details about my work (including downloadable versions of most of my papers). To find my most cited publications and the papers that cite them, use Google Scholar. As an amateur, I have also produced some artwork (photography and painting) and poetry. For a more detailed, formal description of my activities, check my biographical sketch or my extensive Curriculum Vitae. Check my personality profile according to the "Big Five" psychological dimensions.

Expert: Holland, John

Address(es):

http://www.santafe.edu/projects/echo/echo.html

From (Chan, 2001):

John Holland is the founder of the domain of genetic algorithms. Generic algorithms are parallel, computational representations of the processes of variation, recombination and selection on the basis of fitness that trigger most processes of evolution and adaptation. They have been successfully applied to general problem solving, control and optimization tasks, inductive learning (e.g., classifier systems), and the modeling of ecological systems (e.g., the ECHO model).

Expert: Kauffman, Stuart

Professor Emeritas at the University of Pennsylvania, External Professor at the Santa Fe Institute, and Research Professor at the Cell Biology and Physiology The University of New Mexico.

Address(es):

stu.kauffman@worldnet.att.net

Santa Fe Institute, 1399 Hyde Park Road, Santa Fe, NM 87501.

http://www.santafe.edu/sfi/People/kauffman/

From (Chan, 2001):

Stuart Kauffman is a biologist who has tried to understand how networks of mutually activating or inhibiting genes can give rise to the differentiation of organs and tissues during embryological development. His work has led him to investigate the properties of Boolean networks of different sizes and degrees of connectedness. He proposes that the self-organization displayed by such networks of genes or chemical reactions is a vital factor in evolution, corresponding to Darwinian selection by the environment.

Expert: Parrott, Lael (Canadian Expert)

Address(es):

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McGill University, 2000, Office: 429-3, Phone: (514) 343-8032.

http://www.geog.umontreal.ca/geog/Parrotteng.htm

From (Chan, 2001):

Lael Parrott joined the Department of Geography as an assistant professor in June 2001. A native of Vancouver, BC, she earned her MSc. ("The EcoCyborg Project: A model of an artificial ecosystem", 1995) and her PhD ("Learning to engineer life: A generally configurable model for the simulation of artificial ecosystems", 2000) in Biosystems Engineering from McGill University. Before coming to the University of Montreal, she was a research associate at the BITÖK institute (Bayreuth Institute for Terrestrial Ecosystem Research, Bayreuth, Germany) where she worked on individual-based forest stand modelling. In the Department of Geography, Dr. Parrott is pursuing a research program in complex systems with an emphasis on the study of ecological complexity. This research program involves the synthesis of knowledge from multiple disciplines, including ecology, geography, engineering and information technologies, with the aim of gaining a better understanding of the nature and origins of complexity in ecosystems. With the use of object-based models, and through the analysis of field data, she is attempting to characterise and explain phenomena such as emergence, self-organisation, and other aspects of non-linear dynamics in natural systems in order to better understand how human interventions can influence the environment. A long-term objective is to create a collective Earth-system model incorporating human, ecological and physical systems in order to study such questions at the planetary scale. Dr. Parrott's other interests include mult-agent systems, artificial life, and ecological engineering applied to the creation and restoration of ecosystems. Lael Parrott is an active member of GREFi (Interuniversity research group in forest ecology) and a user of the RQCHP (Quebec high performance computing network).

Expert: Prigogine, Ilya (Died in 2003)

Address(es):

annie@physics.utexas.edu

http://order.ph.utexas.edu/Prigogine.htm

From (Chan, 2001):

Ilya Prigogine, was a Nobel laureate chemistry in 1977 for his contributions to non-equilibrium thermodynamics, has studied the theory of dissipative structures. His work on dissipative structures has stimulated many scientists throughout the world and may have profound consequences for our understanding of biological systems. Prigogine aims for a better understanding of the role of time in the physical sciences and in biology. He has contributed significantly to the understanding of irreversible processes, particularly in systems far from equilibrium.

Expert: **Rocha, Mateus Luis**

Address(es):

rocha@lanl.gov

rocha@santafe.edu

University of Hertfordshire, College Lane, Hatfield, Herts. AL10 9AB, United Kingdom, Tel. 0044 (0)1707 284000, Fax. 0044 (0)1707 284870. or

Complex Systems Modeling, Modeling, Algorithms, and Informatics Group (CCS-3), Los Alamos National Laboratory, MS B256, Los Alamos, New Mexico 87545, USA, e-mail:

http://informatics.indiana.edu/rocha/

From the web site:

Luis M. Rocha is an Associate Professor of Informatics and Computer Science, core faculty of the Cognitive Science Program, and affiliated with the Biocomplexity Institute of the University of Indiana, Bloomington, USA. He is also the director of the Computational Biology Collaboratorium and in the Direction of PhD program in Computational Biology at the Instituto Gulbenkian da Ciencia, Portugal.

Expert: **Semura, Jack**

Address(es):

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Department of Physics, Portland State University, Portland, OR 97207-0751, 376 Science 2, Office (503) 725-4229, Fax (503) 725-3888.

http://www.physics.pdx.edu/~semuraj/

From the web site:

Dr. Jack Semura works in the Physics Department at Portland State University. He also teaches with the Science Cornerstone Program at Portland State University, works with the Environmental Sciences and Resources Ph.D. Program, and is an associate with the Science Integration Institute. His research interests are in statistical physics, including complex systems, maximum entropy methods, statistical distributions, generalized thermodynamics, biological statistical physics, connectivity, phase transitions, nucleation, evolutionary computation, phase transitions, and transient heat transfer in cryogenic liquids.

Expert: **Salomaa, Kai T. (Canadian Expert)**

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School of Computing, Queen's University, Kingston, Ontario, Canada, K7L 3N6, Tel: (613) 533-6073, Fax: (613) 533-6513.

http://www.cs.queensu.ca/~ksalomaa/

From the web site:

Dr Salomaa's research belongs to the general area of theory of computation. His current research interests include:

- *descriptional complexity of automata and grammars*
- *state-complexity of finite automata, algorithms for automata operations and implementation*
- *nondeterminism measures for (pushdown) automata, complexity of parsing*
- *synchronization expressions for parallel processes; fairness and trajectories*
- *tree automata and term rewriting systems: modularity and decidability*

Expert: Smiley, Alison (Canadian Expert)

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hfn@hfn.ca

118 Baldwin Street, Toronto, Ontario, M5T 1L6, Tel: 416.596.1252, Fax: 416.596.6946

http://www.hfn.ca/index.html

From the web site:

President of Human Factors North Inc., Adjunct Professor in the Department of Mechanical and Industrial Engineering, University of Toronto and Adjunct Professor in the Department of Civil Engineering, Ryerson University. Dr. Smiley has over 30 years experience in human factors research and application. She has conducted numerous field experiments using various test batteries, driving simulators and instrumented cars to look at the effects of shiftwork, medical conditions, experience, fatigue, lighting, alcohol and drugs on performance. She has conducted large scale experimental studies involving assessment of legibility, comprehension and information load of highway signs. In 1986 she acted as a human factors expert witness in relation to work-rest schedules at the Royal Commission on the Hinton Rail Collision. Since then, she has been involved as expert witness in over 150 legal cases concerning automobile, train and boat accidents. Dr. Smiley is a fellow and past president of the Association of Canadian Ergonomists and was the first chair of the Canadian College for the Certification of Professional Ergonomists (CCCPE, 1998-2002). She is a member of the Canadian National Committee of Uniform Traffic Control Devices, a member and past Chair (1989-1996) of the U.S. Transportation Research Board Committee AND10 on Vehicle User Characteristics, past Chair

(1999-2001) of the TRB Group 3 Council on Operations, Safety and Maintenance of Transportation, and was a member of the TRB Committee advising the U.S. DOT on its Intelligent Vehicle Initiative research program. She is on the Editorial Board of Accident Analysis & Prevention (1996-2005). Dr. Smiley was the recipient of the 1997 A.R. Lauer Safety Award given by the U.S. Human Factors and Ergonomics Society for outstanding contributions to the human factors aspects of highway safety.

Expert: Soltys, Michael (Canadian Expert)

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http://www.cas.mcmaster.ca/~soltys/

From the web site:

Dr Soltys completed my PhD in 2001, at the University of Toronto, under the supervision of Stephen Cook. He is interested in algorithms and computational complexity.

Expert: Stacey, Ralph

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University of Hertfordshire, College Lane, Hatfield, Herts. AL10 9AB, United Kingdom, Tel. 0044 (0)1707 284000, Fax. 0044 (0)1707 284870.

http://www.herts.ac.uk/business/centres/cmc/stacey.htm

From the web site:

Ralph Stacey is Professor of Management and Director of the Complexity and Management Centre at the Business School of the University of Hertfordshire in the UK. He is also a consultant to managers at all levels across a wide range of organizations in many countries and the author of a number of books and articles which have been translated into other languages: these include Managing the Unknowable (published by Jossey- Bass, and in the UK by Kogan Page as Managing Chaos in 1992), Chaos Frontier (published by Butterworth- Heinemann in 1991), Strategic Management and Organizational Dynamics (published by Pitman, now in its 2nd edition 1996) and Complexity and Creativity in Organizations (published by Berrett- Koehler in 1996). He recently completed training as a group therapist at the Institute of Group Analysis in London. His current research has been focussed on: Group dynamics and Human agency in complex responsive networks.

Expert: Wolfram, Stephen

Address(es):

sw-staff@wolfram.com

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Wolfram Research, Inc., 100 Trade Center Drive, Champaign, IL 61820-7237, USA

http://www.stephenwolfram.com/

From the web site:

Stephen Wolfram is a scientist, author, and business leader. He is the creator of Mathematica, the author of A New Kind of Science, and the founder and CEO of Wolfram Research. His career has been characterized by a sequence of original and significant achievements. Born in London in 1959, Wolfram was educated at Eton, Oxford, and Caltech. He published his first scientific paper at the age of 15, and had received his Ph.D. in theoretical physics from Caltech by the age of 20. Wolfram's early scientific work was mainly in high-energy physics, quantum field theory, and cosmology, and included several now-classic results. Having started to use computers in 1973, Wolfram rapidly became a leader in the emerging field of scientific computing, and in 1979 he began the construction of SMP--the first modern computer algebra system--which he released commercially in 1981. In recognition of his early work in physics and computing, Wolfram became in 1981 the youngest recipient of a MacArthur Prize Fellowship. Late in 1981 Wolfram then set out on an ambitious new direction in science aimed at understanding the origins of complexity in nature. Wolfram's first key idea was to use computer experiments to study the behavior of simple computer programs known as cellular automata. And starting in 1982 this allowed him to make a series of startling discoveries about the origins of complexity. The papers Wolfram published quickly had a major impact, and laid the groundwork for the emerging field that Wolfram called "complex systems research." Through the mid-1980s, Wolfram continued his work on complexity, discovering a number of fundamental connections between computation and nature, and inventing such concepts as computational irreducibility. Wolfram's work led to a wide range of applications--and provided the main scientific foundations for such initiatives as complexity theory and artificial life. Wolfram himself used his ideas to develop a new randomness generation system and a new approach to computational fluid dynamics--both of which are now in widespread use. Following his scientific work on complex systems research, in 1986 Wolfram founded the first research center and the first journal in the field.

Expert: Yu, Sheng (Canadian Expert)

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Department of Computer Science, The University of Western Ontario, London, Ontario, Canada, N6A 5B7, Phone: (519) 661-3715, Fax: (519) 661-3515

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From the web site:

Research Interests:

- *Automata and formal language theory and implementation*
- *Object-oriented modeling methodologies and languages*
- *Parallel processing, in particular, parallel programming languages*

5 Organizations

Organization: Ackoff Center for Advancement of Systems Approaches

Web site(s):

http://acasa.upenn.edu/

From the web site:

We are striving to create a Center of Excellence in "Systems Thinking" in collaboration with a number of schools at the University of Pennsylvania and a number of corporate partners. We believe that the Ackoff Center should:

- *Dedicate itself to education, research, service, and outreach programs for the purpose of personal, organizational, and community development.*
- *Represent a focal point (i.e., knowledge and competency bank) for all Systems- Thinking-related academic activities, research, and practices that are scattered around the globe.*
- *Provide continuity to the pioneering work guided by the philosophy created at Penn by Edgar Arthur Singer, Jr. and practiced by a number of luminaries at Penn including Russell Ackoff (in honor of whom the Center is named: the Ackoff Center for Advancement of Systems Approaches).*
- *Develop a critical mass of integrated ideas and approaches that will enable the Center to evolve into a world-class institution through mutually beneficial and cooperative relationships with other centers interested in the advancement of Systems Thinking and systems education.*
- *Bridge the gap between the "soft" and "hard" sciences as it relates to systems science, and between engineering and the humanities.*
- *Extend its offerings beyond the walls of the University. Through the application of information technology and the Internet, the Center should be able to offer distance and distributed learning.*

Organization: BACH Group

Web site(s):

http://www.cscs.umich.edu/about/about.html

From the web site:

With generous support from the University of Michigan Office of the Vice President for Research (OVPR), the Program for the Study of Complex Systems was established in 1995 under the directorship of Prof. Robert Savit (Physics), and became a Center in 1999 under the directorship of Prof. Carl Simon (Math, Public Policy). Its more than 50 participating faculty represent nearly

every college of the University. More than half of these take an active role in CSCS including participation in grant proposals, research groups and administration. In July 2005, CSCS formally became part of the College of Literature, Sciences and the Arts (LS&A).

Key founding members of CSCS were a now-legendary group of researchers known as the BACH Group. The group began meeting over 20 years ago and is made up of researchers from a variety of disciplines who share an interest in complex adaptive systems of all kinds. The original members were Arthur Burks, Bob Axelrod, Michael Cohen and John Holland (BACH). Besides the original members, the BACH Group has included: William Hamilton (Biology), Douglas Hofstadter (Cognitive Science), Reiko Tanese (Cognitive Science), Michael Savageau (Microbiology), and Melanie Mitchell (Cognitive Science and Computer Science). A photo of the current BACH group appears on our home page. They are: Bob Axelrod (Political Science), Michael Cohen (Information), John Holland (Psychology and EECS), Carl Simon (CSCS, Math and Public Policy), Scott Page (Political Science, CSCS), Mark Newman (Physics, CSCS), Mercedes Pascual (EEB) and Rick Riolo (CSCS).

In addition to the BACH group, there are Primary Complex Systems Faculty who do complex systems research, teach a complex systems course and help administer the Center and Associated Complex Systems Faculty whose research includes complex systems and who occasionally attend CSCS events. Please click on the following links for more information about:

CSCS Goals:

- *The activities of CSCS are driven by the following goals:*
- *To catalyze and encourage research in complex adaptive systems at the University of Michigan*
- *To expand and coordinate educational opportunities in complex adaptive systems at UM*
- *To explore the boundaries and overlaps between the complex systems approach and more traditional approaches within the University and business communities*
- *To form a community of complex systems researchers and students-both at UM and throughout southeast Michigan*
- *To enhance the University of Michigan's world-wide reputation in complex systems research and education*
- *To raise funds through government and foundation grants, private and corporate donations to support CSCS activities.*

CSCS Activities:

- *To accomplish the goals listed above, CSCS has undertaken the following activities:*
- *A weekly Complex Systems seminar series*
- *An annual UM-Santa Fe Institute Workshop*
- *Complex Systems Graduate Certificate Program*
- *An annual Nobel Symposium*

- *Regular co-hosting of conferences on complex systems with other research groups on campus*
- *Regular workshops on complex systems techniques*
- *A complex systems computer laboratory for teaching and research on agent-based models*
- *A CSCS web site (www.cscs.umich.edu)*
- *Complex Systems Advanced Academic Workshop (CSAAW)*
- *Complex Systems Reading Group (CSRG)*
- *Support of interdisciplinary faculty research projects*
- *Coordinated hiring of complex systems faculty in departments across UM*
- *Development of new initiatives and proposals for external funding from government agencies, private foundations and corporate partners.*

Organization: Bristol Center for Applied Nonlinear Mathematics

Web site(s):

http://www.enm.bris.ac.uk/anm/

From the web site:

The Bristol Centre for Applied Nonlinear Mathematics is a £1M EPSRC funded research programme to address both the mathematical themes of the Bristol Laboratory for Advanced Dynamic Engineering (BLADE), and the grand engineering challenge of real-time dynamic substructuring. Building on the internationally leading interdiscipinary base of the Applied Nonlinear Mathematics group, and together with the Laboratory for Advanced Computation and the Department of Mathematics, the centre will address these aims with

- *Five postdoctoral research assistants, appointed on a rolling programme over five years, to work on specific projects within each theme.*
- *A series of workshops and extensive visitor programme centered on the themes.*

Organization: Center for Complex Systems Research, University of Illinois at Urbana-Champaign

Web site and address:

http://www.ccsr.uiuc.edu/index.html

Department of Physics, UIUC, 1110 W Green St, Urbana IL 61801

From the web site:

The Center for Complex Systems Research (CCSR) studies systems that display adaptive, self-organizing behavior and systems that are usually characterized by a large throughput, such as turbulent flow, lightning, and the flow of information through the internet. To describe these complex systems, we develop models and techniques drawn from nonlinear dynamics and chaos, neural nets, cellular automata, artificial life, and genetic algorithms. Each year CCSR organizes and hosts the conference Understanding Complex Systems. The Center for Complex Systems Research has a rich history. Founded in 1986 by Stephen Wolfram, the center was later led by Norman Packard and E. Atlee Jackson. A collection of technical reports and scientific publications of CCSR researchers ranging from cellular automata to entrainment control of chaos, experimental studies of turbulent flows, chaotic electronic circuits, and fractal agglomeration patterns is available.

Organization: Center for Complexity Research

Web site(s):

http://www.ccsr.uiuc.edu/web/Journals.htm

Organization: Center for Military and Strategic Studies

Web site and address:

http://www.cmss.ucalgary.ca/index.html

(University of Calgary, Canada)

University of Calgary, 2500 University Drive N.W., MacKimmie Library Tower 701, Calgary, AB T2N 1N4, Phone: (403) 220-4038, Fax: (403) 282-0594, Email: stratnet@ucalgary.ca.

From the web site:

The Centre for Military and Strategic Studies (CMSS) is a unique and prosperous entity at the University of Calgary. The Centre is a division of the Department of National Defence's Security and Defence Forum, a valuable network of Centres specializing in defence and security studies across Canada. Everyone in the CMSS community is actively involved in research, policy studies and the increasing popularity of both a Masters of Strategic Studies (MSS) program and Special Case PhD program. Research areas are broad but the core area is military studies with an emphasis on hard security. This, however, does not exclude people with other related academic pursuits; CMSS welcomes all forms of thought. Each member of the community specializes in their own area, some of which include Chinese military history, Arctic policy, African terrorism as well as international drug trafficking. As part of the Faculty of Social Science at the University of Calgary, the Centre draws from numerous external departments such as Economics, Anthropology, Political Science, Geomatics and History. Most recently, CMSS joined in an affiliation with the Canadian Peacebuilding Coordinating Committee (CPCC) in Ottawa and welcomed two new faculty positions in Defence Economics and Civil Military Relations. CMSS received two generous donations in 2005 from downtown businesses which made all of these opportunities possible. CMSS continues to be committed to the University of Calgary's core principles that were outlined in the 2005/06 Academic Plan. These include:

- *Enhancing the learning experience*
- *Promoting multidisciplinary inquiry*
- *Enhancing research, discovery and creativity*
- *Promoting a return to the community*

The teaching and research objectives of CMSS reflect these principles. In addition to supporting the academic programs, public awareness of Canada's role in the world is increased through the Distinguished Speaker Series and the numerous conferences CMSS holds each year. The Journal of Military and Strategic Studies, an electronic journal published by CMSS in cooperation with CDFAI, is further evidence of CMSS's commitment to these priorities.

Organization: Center for Social Complexity

Web site and address:

http://socialcomplexity.gmu.edu/

Center for Social Complexity, Krasnow Institute for Advanced Study, 237 Robinson Hall MS 3F4, George Mason University, Fairfax, VA 22030 USA, TEL (703) 993-1402, FAX (703) 993-1399, E-mail: complex@gmu.edu.

From the web site:

The mission of the Center for Social Complexity is "to advance the knowledge frontiers of pure and applied social science, by using and developing computational and interdisciplinary approaches that yield new insights into the fundamental nature of social phenomena at all levels of social complexity-from cognitive networks to the world system." "Pure and applied social science" means both theoretical science and policy analysis. The Center subscribes to the philosophy of exploiting synergistic interactions between purely theoretical and applied policy research. Pure research and problem-oriented research can often profit from each other. The benefits of the pure-applied synergy have been amply demonstrated in the history of the social sciences (e.g., learning, human factors, organizations, governance, conflict resolution, peacekeeping), as well as in the life sciences and the physical sciences. The new Center for Social Complexity at George Mason University aspires to contribute as a scholarly collaboratory of excellence, discovery, and invention, pursuing the highest standards, and functioning as an active, cutting-edge leader and participant in the emerging international computational social science community. The Center seeks opportunities for developing collaborative scientific relations with other centers, as well as with individual scholars dedicated to the advancement of computational social science and allied initiatives.

Organization: Center for the Study of Biological Complexity

Web site and address:

http://www.vcu.edu/csbc/

Center for the Study of Biological Complexity, Eugene P. and Lois E. Trani Center for Life Sciences, P.O. Box 842030 | Richmond, Virginia 23284-2030, Phone: (804) 827-0026.

From the web site:

The mission of the Center is to build an academic community centered on integrative discovery science, systems biology and the principles of complexity to address the challenges of the life sciences revolution of the 21st century. The Center develops and supports critical infrastructure and core capabilities at VCU in genomics, proteomics, and computational systems biology and bioinformatics. Center faculty and fellows apply the mathematical and computational principles of complexity to research, instructional and other scholarly activities in the life sciences.

<u>Organization</u>: Center for the Study of Complex Systems (CSCS)

Web sites and address:

http://www.cscs.umich.edu/

http://www.cscs.umich.edu/research/projects/carReports.html

(University of Michigan)

Center for the Study of Complex Systems, 450 Church Street, The University of Michigan, Ann Arbor, MI 48109-1040, Phone: (734) 763-3301, Fax: (734) 763-9267.

From the web site:

The Center for the Study of Complex Systems (CSCS) is a broadly interdisciplinary program at the University of Michigan designed to encourage and facilitate research and education in the general area of nonlinear, dynamical and adaptive systems. Participating faculty represent nearly every college of the University. The Center is based on the recognition that many different kinds of systems which include self-regulation, feedback or adaptation in their dynamics, may have a common underlying structure despite their apparent differences. Moreover, these deep structural similarities can be exploited to transfer methods of analysis and understanding from one field to another. In addition to developing deeper understandings of specific systems, interdisciplinary approaches should help elucidate the general structure and behaviour of complex systems, and move us toward a deeper appreciation of the general nature of such systems. To further its goals, CSCS supports a number of activities. These include a weekly seminar series, research workshops, an annual symposium on complex systems, designed for a general academic audience, and an annual adaptive systems workshop in collaboration with the Santa Fe Institute. CSCS also sponsors a series of interdisciplinary research interest groups. The Center also supports, in whole or in part, a variety of research projects dealing with complex systems in a diverse set of fields.

<u>Organization</u>: Centre d’étude de la complexité

Web site(s):

http://www.physiomatique.unige.ch/ccs/

From the web site:

Ce centre hors les murs, localisé à l'Université de Genève, résulte de l'intérêt académique de quelques chercheurs et professeurs associés librement pour des approches interdisciplinaires, au sujet de l'étude des interactions et mesures, à différents niveaux, entre les cellules, les organismes, la biosphère, les sociétés humaines et l'environnement. La voie systémique et analytique doit être conjointement utilisée pour décrire de tels systèmes (structure et fonction), loin de l'équilibre et sous le contrôle de quatre logiques: cellulaire, écologique, planétaire (physique, chimique, géologique) et socio-culturelle.

Organization: Chaos UMD (Chaos Group)

Web site(s):

http://www-chaos.umd.edu/chaos.html

From the web site:

The idea that many simple nonlinear deterministic systems can behave in an apparently unpredictable and chaotic manner was first noticed by the great French mathematician Henri Poincaré. Other early pioneering work in the field of chaotic dynamics were found in the mathematical literature by such luminaries as Birkhoff, Cartwright, Littlewood, Levinson, Smale, and Kolmogorov and his students, among others. In spite of this, the importance of chaos was not fully appreciated until the widespread availability of digital computers for numerical simulations and the demonstration of chaos in various physical systems. This realization has broad implications for many fields of science, and it is only within the past decade or so that the field has undergone explosive growth. It is found that the ideas of chaos have been very fruitful in such diverse disciplines as biology, economics, chemistry, engineering, fluid mechanics, physics, just to name a few. Since the mid-1970s, the Chaos Group at Maryland has done extensive research in various areas of chaotic dynamics ranging from the theory of dimensions, fractal basin boundaries, chaotic scattering, controlling chaos, etc. It is hoped that the knowledge we have gained is of use to others, and it is the objective of this web site to disseminate those fruits of labor.

Organization: Colorado Center for Chaos and Complexity

Web site(s):

http://cires.colorado.edu/c4/

From the web site:

The Colorado Center for Chaos & Complexity (C4) was founded in January 1997 to support interdisciplinary education and research, focusing on nonlinear problems that demonstrate complex behavior from simple systems, and simple behavior from complex systems. C4 is administered through the Cooperative Institute for Research in Environmental Sciences (CIRES)

and the [Graduate School] at the [University of Colorado]. The Interim Director of C4 is Professor [Elizabeth (Liz) Bradley].

<u>Organization</u>: Commonwealth Scientific and Industrial Research Organization (CSIRO)

Web site(s):

http://www.cmar.csiro.au/ar/css/intertasks.shtm

From the web site:

The Centre for Complex Systems Science was established through the CSIRO Emerging Science Initiative. It acts as a virtual centre with a small core group in Canberra, supported projects throughout CSIRO and a range of linkage activities. The main activity of the centre is through funding projects in CSIRO Divisions. The centre also supports a range of linkage activities to ensure cross-fertilisation between groups working on complex system science. The linkage activities include Working Groups in specific complex system science areas and Interaction Tasks, focussed on key questions in complex systems science. The centre is managed by an executive, with oversight by a science board. The emerging science areas report to the Emerging Science Oversight Committee chaired by Michael Barber (Executive Director, Science Planning).

<u>Organization</u>: Community Research & Development Information Service (CORDIS)

Web site(s):

http://www.cordis.lu/en/home.html

From the web site:

CORDIS is an information space devoted to European research and development (R&D) and innovation activities. The main aims of CORDIS are: To facilitate participation in European research and innovation activities; To improve exploitation of research results with an emphasis on sectors crucial to Europe's competitiveness; To promote the diffusion of knowledge fostering the innovation performance of enterprises and the societal acceptance of new technology.

- *European Research Area. The service provides a comprehensive view on the concept, the activities and further steps illustrating the lively debate initiated in January 2000. It also includes archive on the FP6 adoption. cordis.europa.eu.int/era*

- *Towards FP7. Towards FP7 provides a gateway to the latest developments on the preparation of the Seventh Framework Programme (FP7) and its essential features. It gives you the latest news and events on FP7 as well as the key milestones towards FP7. cordis.europa.eu.int/fp7*

- *Sixth Framework Programme (FP6) Service (2002-2006). The service offers a step-by-step approach to help understand all activities as well as participation in European*

funding opportunities, for which 17.5 billion euro has been earmarked.
cordis.europa.eu.int/fp6

Organization: Complex Adaptive Systems Group at Iowa State University

Web site(s):

http://www.cs.iastate.edu/~honavar/alife.isu.html

From the web site:

Many natural systems (e.g., brains, immune systems, ecologies, societies) and increasingly, many artificial systems (parallel and distributed computing systems, artificial intelligence systems, artificial neural networks, evolutionary programs) are characterized by apparently complex behaviors that emerge as a result of often nonlinear spatio-temporal interactions among a large number of component systems at different levels of organization. Consequently, researchers in a number of disparate areas including computer science, artificial intelligence, neural networks, cognitive science, computational economics, mathematics, optimization, complexity theory, control systems, biology, neuroscience, psychology, engineering, etc. have have begun to address, through a combination of basic as well as applied, theoretical as well as experimental research, analysis and synthesis of such systems.

Organization: Complex Systems at the University of Buenos Aires

Web site(s):

http://www.cea.uba.ar/aschu/complex.html

(University of Buenos Aires)

Organization: Complex Systems at University of Alaska

Web site(s):

http://complexsystems.uaa.alaska.edu/index.htm

(University of Alaska)

From the web site:

The Complex Systems Group is comprised of faculty members from a wide spectrum of disciplines including: Art, Physics, Chemistry, Public Policy, Nursing, Biology, Mathematics, Philosophy, Computer Science, Logistics, Political Science, Psychology, and other disciplines.

Organization: Complex Systems Laboratory (Université de Montréal, Canada)

Address:

lael.parrott@umontreal.ca

Département de géographie, Université de Montréal, C.P. 6128 succursale centre-ville, Montréal, QC, H3C 3J7

Web site(s):

http://www.geog.umontreal.ca/syscomplex/eng/mainframeset.html

From the web site:

The long-term objective of our research program is to advance scientific understanding of the dynamics of natural systems, and, based on this new understanding, to propose better approaches to environmental management, restoration and protection. This goal is being pursued within the theoretical framework of complex systems studies, a new, multidisciplinary research domain which enables the study and characterisation of the non-linear dynamics of a vast collection of systems, ranging from ecosystems to human societies, biochemical networks to economies. Our current emphasis is on the characterisation and elucidation of the nature of complexity in terrestrial ecosystems. Through the aid of state of the art modelling and analysis tools we are studying the spatial and temporal dynamics of real and simulated ecosystems, working to develop new approaches that will help us better understand "how nature works". A principal objective of this research is to be able to apply complexity theory to the quantification of the consequences of human activity on the health and integrity of the Earth's ecosystems. Current research in the lab is focused on the modelling and simulation of complex spatial and temporal dynamics in terrestrial ecosystems, and on the development of associated methods for describing and characterising ecological complexity. We are also involved in several collaborative projects in which we apply our expertise in complex systems modelling and analysis to the solution of specific problems in biology, geography and resource management. All of our projects involve modelling and/or data analysis. Since we develop novel approaches, we program our own code in MATLAB, C or some other language. Students who do not have previous programming experience are trained in the tools necessary to accomplish their project. Our multidisciplinary team of geographers, biologists, engineers and physicists provides the perfect environment for the exchange of ideas and expertise between the disciplines. With the exception of some fieldwork being carried out on the Gault Nature Reserve (Mont St. Hilaire), we generally collaborate with field ecologists and other scientists rather than doing our own fieldwork. Projects under our research program are grouped under two main research streams: terrestrial ecosystem modelling, and the characterisation of ecological complexity. A third group of collaborative projects involves the application of complexity theory in environmental modelling.

- *Terrestrial ecosystem modelling*
- *Characterisation of ecological complexity*
- *Applications of complexity theory in collaborative environmental modelling projects*

<u>Organization</u>: Complexity Digest

Web site(s):

http://www.comdig.org/

From the web site:

Complexity Digest has been successfully networking the complexity community since fall of 1999. Its editor is Dr Gottfried Mayer, a member of the complexity community since his residence at the Santa Fe Institute in its early days. The sponsor is Dean LeBaron, trustee of SFI and investment commentator. Contributors are welcome to send submissions to editor@comdig.com. ComDig hopes to be of use to all of the growing number of complexity organizations and supported by them. ComDig has been distributed by weekly email to a list of people who request copies free of charge. There will be minimal advertising without interfering with the content. More recently ComDig has been made available through RSS (Real Simple Syndication) and we have made efforts to move from text-based content to web-casts of video and audio files from conferences and interviews.

Organization: Complexity Research Programme

Web site(s):

http://www.psych.lse.ac.uk/complexity/

From the web site:

We take complexity to mean the intricate inter-relationships that arise from the interaction of agents, which are able to adapt in and evolve with a changing environment. The theoretical framework being developed is based on work in the natural sciences (in physics, chemistry, biology, mathematics, and computer simulation) studying complex adaptive systems (CAS). The work at the LSE is focusing on complex social systems using the generic characteristics of CAS as a starting point, but without direct mapping between the disciplines. In other words, organisations are studied as complex social systems in their own right, not as metaphors or analogies of physical, chemical or biological CASs. In an organisational context, complexity provides an explanatory framework of how organisations behave. How individuals and organisations interact, relate and evolve within a larger social ecosystem. Complexity also explains why interventions may have un-anticipated consequences. The intricate inter-relationships of elements within a complex system give rise to multiple chains of dependencies. Change happens in the context of this intricate intertwining at all scales. We become aware of change only when a different pattern becomes discernible. But before change at a macro level can be seen, it is taking place at many micro-levels simultaneously. Hence micro-agent change leads to macro system evolution. Eve Mitleton-Kelly, May 2001.

Organization: Conflict Research Consortium

Web site(s):

http://conflict.colorado.edu/

From the web site:

The University of Colorado Conflict Research Consortium, directed by Guy and Heidi Burgess, was founded in 1988 as a multi-disciplinary center for research and teaching about conflict and its transformation. With its primary focus on difficult and intractable conflicts, the Consortium has pioneered efforts to use rapidly advancing information technologies to provide citizens in all walks of life with the information that they need to deal with conflicts more constructively. The Consortium sees such efforts to enhance and mobilize the skills of the general population as critical to efforts to deal with complex, society-wide conflicts. This work, which dates back to the earliest days of the Internet, has now led to the posting of new versions of CRInfo: The Conflict Resolution Information Source (www.CRInfo.org) and Beyond Intractability, the website of the Intractable Conflict Knowledge Base Project (www.BeyondIntractability.org). These systems, which were constructed with the help of more than 250 experts, offer succinct, executive summary-type articles on almost 400 topics as well as links to recommended sources (Web, print, and audiovisual) of more in-depth information. Also available are over a hundred hours of online interviews, featuring more than 70 distinguished scholars and practitioners, and comprehensive bibliographies with more than 20,000 citations. The Consortium has also produced four online training programs and simulations (one on intractable conflict, one on the framing of environmental conflicts, one on racial conflicts, and another on transformative approaches to conflict. There is also a popular article on civility. Links to these and other Consortium websites and projects are available below.

Comment from DRDC reviewer:

Additional information could be found in 2006 at: http://www.colorado.edu/conflict/transform/

<u>Organization</u>: Discrete Dynamics Lab (DDLab)

Web site(s):

http://www.ddlab.com/

<u>Organization</u>: European Research Consortium for Informatics and Mathematics (ERCIM, 2006)

Web site(s):

http://www.ercim.org/

From the web site:

ERCIM - the European Research Consortium for Informatics and Mathematics - aims to foster collaborative work within the European research community and to increase co-operation with European industry. Leading research institutes from seventeen European countries are members of ERCIM.

<u>Organization</u>: Evolution, Complexity & Cognition Group (ECCO)

Web site and address:

http://pcp.lanl.gov/EVOLCOMP/

Vrije Universiteit Brussel

Comment from DRDC Reviewer:

There were some temporary problems with the access of this web site.

Organization: Evolutionary and Adaptive Systems at Sussex (EASy)

Web site(s):

http://www.informatics.susx.ac.uk/easy/index.html

From the web site:

The Department of Informatics (subsuming the former School of Cognitive and Computing Sciences, COGS) in the University of Sussex at Brighton is home to one of the world's largest groups of researchers studying artificial evolutionary and adaptive systems. Such work is often described using names such as Artificial Life, Evolutionary Computation, and Adaptive Behavior research. Members of the Evolutionary and Adaptive Systems (EASy) group comprise research students and faculty from both Informatics and the School of Life Sciences (formerly the School of Biological Sciences, BIOLS), with very strong links to the interdisciplinary Centre for Computational Neuroscience and Robotics (CCNR). The EASy group offers an M.Sc. degree in Evolutionary and Adaptive Systems, with substantial Engineering and Physical Sciences Research Council (EPSRC) funding. As of 2003, the EASy group numbers about 70 people from Postgraduate level upwards.

Organization: Federal Aviation Administration, ATO Operations Planning, NAS Human Factors Group

Web site(s):

http://hf.tc.faa.gov/default.htm

From the web site:

The National Airspace System (NAS) Human Factors Group employs scientific methods and advanced technology in the conduct of research and development to ensure that systems that include human operators and maintainers perform as effectively and safely as possible. The members of the NAS Human Factors Group have a broad range of skills, knowledge, and experience that distinguishes them from other organizations conducting human factors work for the Federal Aviation Administration (FAA). In addition to having graduate training in human factors, psychology, engineering, and related fields, we have studied air traffic control, NAS maintenance, and flight deck operations by working closely with current controllers, technicians, and pilots. We use the William J. Hughes Technical Center (WJHTC) laboratories that contain all the current and developmental systems in the NAS, and regularly visit FAA field facilities to observe and collect data about their operations. The Human Factors Specialists speak the users'

language while maintaining a scientific, human-centered, system-oriented perspective. Within the Research, Development, and Human Factors Laboratory (RDHFL), we conduct research to develop methods of measuring human performance in the aviation environments, to evaluate longer term operational concepts, and to develop useful databases and design standards. The R&D Labs Group provides outstanding technical, engineering, and computer science support to these efforts. Together, we have developed high fidelity rapid prototyping and human-in-the-loop simulation capabilities coupled with specialized human operator and system performance measures. Finally, we use this information and methods to work with stakeholder groups to evaluate existing systems and to design nearer term developmental systems and procedures to ensure that the operators and maintainers can use them safely and effectively to perform their critical jobs. The collocation and collaboration between the research and acquisition personnel and activities increases the relevance and quality of our products. The human-centered design processes are intended to make these frequently complex systems relatively easy to learn and use so as to increase productivity and efficiency while minimizing the potential for error. Our focus is on designing systems and procedures for the NAS that meet the needs of the operators and maintainers, and ultimately the FAA customers (pilots, airlines, commercial operations, and the traveling public) rather than on trying to select, train, and manage people that can use technology-centered systems.

Comments from DRDC reviewer:

This Organization publishes results from works that are often directly related to complexity. They consider human factors, how to present information to controllers, how to simplify complexity to controllers, equipment evaluation, etc.

Organization: FRIAMGroup

Web site(s):

http://www.friam.org/

From the web site:

FRIAMGroup is an emergent organization of Complexity researchers and software developers in Santa Fe, New Mexico interested in Agent-Based Modeling, Applied Complexity, Artificial Life, Evolutionary Computation and Swarm Intelligence. A significant amount of of the interactions for FRIAMGroup occur through the mailing list. New members interested in our topic space are encouraged to subscribe at http://redfish.com/mailman/listinfo/friam_redfish.com. The FRIAMGroup sponsors a lecture series to explore theory, technology and case-studies in Applied Complexity. Dates and topics for upcoming talks will be posted as they are determined (planned to occur roughly monthly). Talks are usually hosted at the Santa Fe Institute in the Medium Conference room or at the conference room at 624 Agua Fria Sreet. Our thanks to Santa Fe Institute and Santa Fe Economic Development, Inc. (SFEDI) for their support. All talks are open to the public.

Organization: Human Complex Systems

Web site(s):

http://hcs.ucla.edu/

From the web site:

We explore complex systems inhabited by human beings. These systems are biological, social, cultural, technological and creative. Our method is to analyze the behavior of the inhabitants of these systems and their interactions. Many interactions are indirect with multiple causes and effects. Also, we construct computer models, synthesize virtual worlds, and run simulation experiments. Our computational methods use software agents. Systems might be teams, families, nations or companies. Agents inhabit these systems. The agents interact; they communicate; and they have minds of their own and models of their world. They use these models to learn and adapt. From myriad interactions arise complex emergent global patterns and structures (narratives, lives, cultures, economies and institutions). Multi-agent virtual worlds serve as experimental laboratories to explore intuitions and "what-if" scenarios. We observe agents learning and adapting. Also, models provide insights or predictions that can be validated and calibrated against real world data. Results help us design better high-performing real-world systems with checks and balances. These systems are robust because they attend to: limited knowledge, distributed thinking, individual interaction, bounded rationality, subjective values, environmental change, and diverse world views. Research here is exciting, vibrant and innovative. It addresses questions faced everyday by decision-makers in business and government. We explore the implications of local actions for global patterns, and conversely, the influence of global structures on local behavior. Order and understanding come from chaos, competition, diversity, evolution and emergence.

Organization: Information Society Technologies (Future Emerging Technologies)

Web site(s):

http://www.cordis.lu/ist/fet/co.htm#workprogramme

From the web site:

Welcome to the homepage of the proactive initiative in 'complex systems'. FET is committed to invest into 'complex system' research as it will allow to explore new design and control paradigms and lead to the conceptual breakthroughs necessary to conceive the next generation of information technologies. In order to be successful research has to be balanced between focus on IT core problems and the need to explore concepts in complex systems in a multitude of domains. The information revolution has relied on our capacity to extend - with much ingenuity - Moore's law over several decades. In time, however, we will reach a fundamental barrier for design and control of systems: the complexity limit. Systems become increasingly larger and have ever more components and information flow in the system increases exponentially. Mastering their complexity - the high level of interdependence between their often very heterogeneous components - becomes a major hurdle threatening to slow down the information revolution. Designing, controlling, modelling and monitoring behaviour of such systems are the fundamental challenges that the CS initiative addresses. We need new paradigms as we are rapidly moving from systems based on closed hierarchical structures to open and distributed, networked organisations. Recent studies of complex systems as they occur in nature, society or even engineering - whether these are living organisms, animal societies, ecosystems, markets, cultural

groupings, or the Internet -suggest that we can learn lessons from these systems on how to design and control a new generation of complex IT systems. These aspects were emphasised in a [call in 2003](). The [call in 2005]() addresses the specific issue of simulation of complex systems. In the last decade almost every branch of science and technology has made use of advanced computing and information technologies. This convergence of computing with the sciences and technology is creating a revolution in the very nature of scientific discovery and technological design. The need for simulation as a tool of design and scientific analysis arises in many areas: For many systems, simulation is the only practicable method of developing an understanding of their properties - sometimes replacing, sometimes complementing experimentation For instance in molecular biology, revolutionary novel methods of data acquisition are providing a wealth of information that combined with more powerful means of analysis could advance our understanding of living systems to entirely new levels. In technology, simulation is often the only feasible way for (a priori) validation of system behaviour. In society, simulation could help inform decisions about inherently complex matters such as national security, the deployment of new technologies, or environmental policies. New computational approaches must be found to tackle the resulting challenges and to continue the momentum of this 'new era' of convergence of computing with science and technology. Understanding the properties of 'complex systems' with a large number of highly interconnected heterogeneous elements poses today a grand challenge for system research. Examples of such systems include the Internet, critical infrastructures -like computer networks or power grids - and signalling and regulatory networks in biology. For such systems we can design components and their connections but the problem remains of how to guide them to achieve desired global behaviours, like dependability and adaptability, and how to predict and avoid undesired behaviours, like cascading failures in interconnected infrastructures. In the life sciences, novel data acquisition techniques provide a wealth of data on living systems but we lack sufficient means to infer models from these data. We lack a framework of mathematical and computational techniques for simulation and modelling of complex systems in the context of complex systems in engineering and science. The objective is therefore to develop scalable computational modelling and inference tools and scalable simulation techniques for complex systems and in particular to:

- *Infer system models - the dynamic laws governing the components and their interactions - from high volume, possible incomplete or uncertain data.*
- *Develop models of emergence of aggregate behaviour that will permit the formulation of design strategies for systems with a specified aggregate behaviour.*

One or more of the following research issues encountered across many applications should be addressed:

- *Multi-scale simulations: Develop methods for the effective computation of systems acting/described on different levels of aggregation. Underlying issues include:*
- *Model embedding: How to link simulations on different scales*
- *Formal languages to model systems in a modular and compositional way.*
- *Hierarchical structures from aggregation: emergence of higher level behaviour.*
- *Simulation in presence of uncertainty: Develop computational tools that take into account the fact that the models themselves as well as the parameters that they use may be uncertain*

- *Reconstruction of system models from incomplete, missing or inconsistent sets of data. In many fields experiments to back up simulation are not always possible and we need to validate data by combining them with simulation results and complementary data.*
- *Integrated modelling and simulation environments: Matching large amounts of data against models - to tune and validate them - imposes integration of simulation modules and high-throughput sources of experimental data.*

Organization: Institute for Complexity Sciences (ICS)

Web site and address:

http://labmag.di.fc.ul.pt/icc/index.html?

Institute for Complexity Sciences Palácio Burnay, Rua da Junqueira, nº 86, 1300 – 344 Lisboa, Portugal.

Helder Coelho (hcoelho@di.fc.ul.pt)

Tanya Araújo (Tanya@iseg.utl.pt)

Jorge Louçã (jorge.l@iscte.pt)

From the web site:

The Institute for Complexity Sciences supports research in Complexity domains,promoting knowledge in interdisciplinary subjects and applying scientificmethodologies to socially relevant problems. ICC goals: a) Promote interdisciplinary collaboration in scientific domains where the notion of complexity has an essential role; b) Support the development of a common language between mathematicians, physicians, economists, sociologists, biologists, linguists and computation scientists, as well as to maintain a forum, opened to researchers in the above domains, allowing crossed fertilization of their disciplines; c) Provide services to the community; d) Cooperate with public and private entities, concerning mutual interests in the domain of research, education and services to community; e) Promote contacts and cooperation with foreign universities and research centers and international entities; f) Organize advanced education courses.

Organization: Institute for Nonlinear Science

Web site and address:

http://inls.ucsd.edu/

Institute for Nonlinear Science, UCSD, 9500 Gilman Drive, La Jolla, CA 92093-0402, Phone +1-858-534-4068, FAX +1-858-534-7664.

From the web site:

The Institute for Nonlinear Science (INLS) is an Organized Research Unit at the University of California San Diego (UCSD). This is an academic research unit of the University of California dedicated to interdisciplinary research and training of graduate students. Students at UCSD are admitted to disciplinary programs in academic departments, but may pursue their dissertation research within the laboratories of INLS. (UCSD). The research interests at the institute comprise various investigations into and applications of nonlinear dynamics. The topics of investigation vary over time. At the present the main subjects include chaotic communications and the nonlinear dynamics of neural systems. In each area of research at INLS both the experimental and numerical/theoretical approaches are central themes. For more details on the research efforts, please see our research page. The institute is located in the Center for Magnetic Recording (CMRR) building on the UCSD campus in La Jolla close to the Geisel Library and the Price Center. Refer to the contact page for directions and the full address. From the UCSD maps webpage one can retrieve a map of the campus to locate INLS. Research is conducted by a variety of faculty, researchers, postdocs, PhD students and undergraduates both affiliated and visiting staff. For a list of people currently active at INLS please refer to the people page.

Organization: Institute for the Future

Web site(s):

http://www.iftf.org/

From the web site:

The Institute for the Future (IFTF) is an independent nonprofit research group. We work with organizations of all kinds to help them make better, more informed decisions about the future. We provide the foresight to create insights that lead to action.

We bring a combination of tools, methodologies, and a deep understanding of emerging trends and discontinuities to our work with companies, foundations, and government agencies. We take an explicitly global approach to strategic planning, linking macro trends to local issues in such areas as:

- *Work and daily life*
- *Technology and society*
- *Health and health care*
- *Global business trends*
- *Changing consumer society*

The Institute is based in California's Silicon Valley, in a community at the crossroads of technological innovation, social experimentation, and global interchange. Founded in 1968 by a group of former RAND Corporation researchers with a grant from the Ford Foundation to take leading-edge research methodologies into the public and business sectors, the IFTF is committed to building the future by understanding it deeply.

Organization: Institute for the Study of Coherence and Emergence (ISCE)

Web site(s):

http://www.isce.edu/

From the web site:

The Institute for the Study of Coherence and Emergence (I.S.C.E.) originally grew out of the New England Complex Systems Institute's Organizational-Related Programmes department in mid-1999. The main aim of ISCE is to facilitate the conversation between academics and practitioners regarding the implications of complexity thinking for the management of organizations. To support this aim I.S.C.E. organizes a variety of events and also publishes the international interdisciplinary journal, Emergence: Complexity and Organizations (formerly known as Emergence), or simply, E:CO. In December 2004 ISCE was renamed the ISCE Group and our main activities were split into different divisions to facilitate the management of these separate (though certainly not independent) activities. The ISCE Group comprises three divisions, namely: ISCE Research, ISCE Publishing and ISCE Events.

<u>Organization</u>: Institute for the Study of Complex Systems (ISCS)

Web site(s):

http://www.complexsystems.org/

From the web site:

Welcome to the Home Page for the Institute for the Study of Complex Systems (ISCS), a research organization, that specializes in evolutionary/functional approaches to complexity. The director of the ISCS is Peter A. Corning, Ph.D., who is known especially for his work on the causal role of synergy in evolution, most notably in his book The Synergism Hypothesis (McGraw-Hill, 1983) and in Nature's Magic: Synergy in Evolution and the Fate of Humankind (Cambridge Univ., 2003). Current work at the Institute also includes a new approach to the relationship between thermodynamics and biology called "thermoeconomics", a new, cybernetic approach to information theory called "control information.", and research on basic needs under the "Survival Indicators" Program.

<u>Organization</u>: Integrative Graduate Education and Research Traineeship (IGERT)

Web site and addresses:

http://www.chaos.cornell.edu/

(Cornell University)

Bridget Meeds, bm24@cornell.edu, IGERT Program Assistant, Center for Applied Math, 657 Rhodes Hall, Cornell University, Ithaca, NY 14853-3801, 607-255-4335

Professor John Guckenheimer, gucken@cam.cornell.edu, IGERT Director, Center for Applied Math, 657 Rhodes Hall, Cornell University, Ithaca, NY 14853-3801

From the web site:

The subject of nonlinear systems is wonderfully broad and has important applications in fields ranging from physics, mechanical engineering and computer science to the life sciences, sociology and finance. A mathematics student studying dynamical systems, a physiologist studying the heart and a computer scientist studying the internet are all studying nonlinear phenomena. Yet, they are unlikely to cross paths in traditional graduate programs. In contrast, the Nonlinear Systems Program brings together doctoral candidates enrolled in diverse graduate fields for broad multidisciplinary training in nonlinear systems early in their graduate careers. The program encourages students to engage in research that combines theory, computation and empirical data. The Integrative Graduate Education and Research Traineeship (IGERT) program seeks to train PhD scientists and engineers with the interdisciplinary background and the technical, professional and personal skills needed to address the global questions of the future. Through the use of innovative curricula and internships, and by focusing on problem-centered training, these programs give their graduates the edge needed to become leaders in their chosen fields.

Organization: International Society for Complexity, Information, and Design (ISCID)

Web site(s):

http://www.iscid.org/

From the web site:

The International Society for Complexity, Information, and Design (ISCID) is a cross-disciplinary professional society that investigates complex systems apart from external programmatic constraints like materialism, naturalism, or reductionism. The society provides a forum for formulating, testing, and disseminating research on complex systems through critique, peer review, and publication. Its aim is to pursue the theoretical development, empirical application, and philosophical implications of information- and design-theoretic concepts for complex systems.

Organization: International Society for Adaptive Behavior

Web site(s):

http://www.isab.org/

From the web site:

The International Society for Adaptive Behavior, ISAB, is an international scientific society devoted to education and furthering research on adaptive behavior in animals, animats, software agents, and robots. The Society's principal activities at present are: the publication of the Journal of Adaptive Behavior; the organisation of the biennial International Conference on the Simulation of Adaptive Behavior (SAB); the sponsorship of other workshops and conferences on adaptive behavior; facilitating the exchange of information about events, job opportunities, and research results in adaptive behaviour.

Organization: International Society for the Systems Sciences

Web site(s):

http://www.isss.org/

From the web site:

The International Society for the Systems Sciences (ISSS) is among the first and oldest organizations devoted to interdisciplinary inquiry into the nature of complex systems, and remains perhaps the most broadly inclusive. The Society was initially conceived in 1954 at the Stanford Center for Advanced Study in the Behavioral Sciences by Ludwig von Bertalanffy, Kenneth Boulding, Ralph Gerard, and Anatol Rapoport. In collaboration with James Grier Miller, it was formally established as an affiliate of the American Association for the Advancement of Science in 1956. Originally founded as the Society for General Systems Research, the society adopted its current name in 1988 to reflect its broadening scope (see Note on History of SGSR/ISSS). Founders of the Society for General Systems Research: Ludwig von Bertalanffy, Kennet Boulding, Ralph Gerard, James Grier Miller and Anatol Rapoport.

The initial purpose of the society was "to encourage the development of theoretical systems which are applicable to more than one of the traditional departments of knowledge," with the following principal aims:

- *to investigate the isomorphy of concepts, laws, and models in various fields, and to help in useful transfers from one field to another;*
- *to encourage the development of adequate theoretical models in areas which lack them;*
- *to eliminate the duplication of theoretical efforts in different fields; and*
- *to promote the unity of science through improving the communication among specialists.*

In the intervening years, the ISSS has expanded its scope beyond purely theoretical and technical considerations to include the practical application of systems methodologies to problem solving. Even more importantly, it has provided a forum where scholars and practitioners from across the disciplinary spectrum, representing academic, business, government, and non-profit communities, can come together to share ideas and learn from one another.

Organization: International Society of Artificial Life (ALife.org)

Web site(s):

http://www.alife.org/

From the web site:

The International Society for Artificial Life (ISAL) was established in May of 2001 as a non-profit organization. Currently based at Reed College, ISAL is a democratic, international, professional society dedicated to promoting scientific research and education relatingto artificial life, including sponsoring conferences, publishing scientific journals and newsletters, and maintaining

web sites related to artificial life. Artificial Life (published by MIT Press) is the official journal of ISAL, and the biannual International Conference on Artificial Life is the official scientific gathering of the Society.

Organization: Israel Institute of Technology (Technion)

Web site(s):

http://www.cemethod.org

From the web site:

(The Cross-Entropy Method)

This web site is a collection of information and links about the Cross-Entropy method. Pioneered in 1997 by Reuven Rubinstein as an efficient method for the estimation of rare-event probabilities, the cross-entropy (CE) method has rapidly developed into a powerful and versatile technique for both rare-event simulation and combinatorial optimisation. The method derives its name from the cross-entropy (or Kullback-Leibler) distance - a well known measure of "information", which has been successfully employed in diverse fields of engineering and science, and in particular in neural computation, for about half a century. The CE method is an iterative method, which involves the following two phases: 1- Generation of a sample of random data (trajectories, vectors, etc.) according to a specified random mechanism; 2- Updating the parameters of the random mechanism, on the basis of the data, in order to produce a "better" sample in the next iteration. The significance of the cross-entropy concept is that it defines a precise mathematical framework for deriving fast, and in some sense "optimal" updating/learning rules. The CE method has been successfully applied to a number of difficult combinatorial optimization problems, including the maximal cut problem, the traveling salesman problem (TSP), the quadratic assignment problem, different types of scheduling problems, the clique problem, the buffer allocation problem (BAP) for production lines, and combinatorial optimization problems associated with the genome. It is important to note that the CE method deals successfully with both deterministic problems, such as the TSP, and noisy (i.e., simulation-based) problems, such as the BAP. An approach closely related to CE is the Probability Collectives work of Dr. David Wolpert and his collaborators. This approach uses information theory as a bridge to relate game theory, statistical physics, and distributed optimization/control. In the field of rare-event simulation, CE is used in conjunction with the importance sampling (IS) technique: the CE method iteratively optimizes parameters of the distributions used in the simulation. Applications include the efficient estimation of performance measures in telecommunication networks and reliability systems.

Organization: NCARAI ~ Intelligent Systems

Web site and address:

http://www.nrl.navy.mil/aic/iss/

POC: Head, Intelligent Systems Section, Code 5515, Naval Research Laboratory, Washington DC 20375, (202) 767-2684 fax: (202) 767-3172, email: w5515-iss@aic.nrl.navy.mil

From the web site:

The Intelligent Systems Section at the Navy Center For Applied Research in Artificial Intelligence (NCARAI) performs state-of-the-art research in machine learning, intelligent autonomous systems, intelligent decision aids,robotics, and software and hardware for sensing and perception. Applications include autonomous vehicles, (including autonomous underwater vehicles, autonomous micro-air vehicles, and tactical mobile robots), lessons-learned systems, and decision aids for military planning systems. NCARAI techniques contribute to more intelligent systems that require less human intervention, and allow faster, less-exensive development of autonomous systems and vehicles.

<u>Organization</u>: Neurosciences Institute

Web site(s):

http://www.nsi.edu/public/

From the web site:

The Neurosciences Institute is an independent, not-for-profit, privately supported, scientific research organization dedicated to studying the workings of the brain at the most fundamental level. Its goal is to illuminate the biological principles that form the very essence of conscious life: sensory perception, physical movement, memory, emotion, and communication. The Institute is dedicated to a research environment that encourages creativity and innovation in a collaborative atmosphere with true freedom of scientific inquiry, in the expectation that such an environment provides the best chance for making vital advances for the benefit of mankind. Under the leadership of Gerald M. Edelman, M.D., Ph.D., the Institute was founded in New York in 1981, moved to temporary quarters in La Jolla in 1993, and in 1995 to this award-winning architectural complex designed by Tod Williams Billie Tsien and Associates.

<u>Organization</u>: New England Complex Systems Institute (NECSI)

Web site and address:

http://necsi.org/

NECSI, 24 Mt. Auburn St., Cambridge, MA 02138, TEL 617-547-4100, FAX 617-661-7711, necsi@necsi.org

From the web site:

The New England Complex Systems Institute (NECSI) is instrumental in the development of complex systems science and its applications. NECSI conducts research, education, knowledge dissemination, and community development around the world for the promotion of the study of complex systems and its application for the betterment of society. NECSI was founded by faculty of New England area academic institutions in 1996 to further international research and understanding of complex systems. Complex systems is a new field of science that aims to understand how parts of a system give rise to the system's collective behaviors, and how it

interacts with its environment. These questions can be studied in general, and they are also relevant to all traditional fields of science. Social systems formed (in part) out of people, the brain formed out of neurons, molecules formed out of atoms, and the weather formed from air flows are all examples of complex systems. The field of complex systems intersects all traditional disciplines of physical, biological and social sciences, as well as engineering, management, and medicine. Advanced education in complex systems attracts professionals, as complex systems science provides practical approaches to health care, social networks, ethnic violence, marketing, military conflict, education, systems engineering, international development and terrorism. The study of complex systems is about understanding indirect effects. Problems we find difficult to solve have causes and effects that are not obviously related. Pushing on a complex system "here" often has effects "over there" because the parts are interdependent. This has become more and more apparent in our efforts to solve societal problems or avoid ecological disasters caused by our own actions. The field of complex systems provides a number of sophisticated tools, some of them conceptual helping us think about these systems, some of them analytical for studying these systems in greater depth, and some of them computer based for describing, modeling or simulating them. NECSI research develops basic concepts and formal approaches as well as their applications to real world problems. To date, the contributions of NECSI researchers include studies of networks, agent-based modeling, multiscale analysis and complexity, chaos and predictability, evolution, ecology, biodivesity, altruism, systems biology, cellular response, health care, systems engineering, negotiation, military conflict, ethnic violence, and international development. NECSI uses many modes of education to further the investigation of complex systems. Throughout the year, classes, seminars, conferences and programs assist students and professionals alike in their understanding of complex systems. Courses have been taught all over the world: Australia, Canada, China, Colombia , France, Italy, Japan, Korea, Portugal, Russia and many states of the U.S. NECSI also sponsors postdoctoral fellows, provides research resources, and hosts the International Conference on Complex Systems, discussion groups and web resources. The New England Complex Systems Institute is comprised of a general staff, a faculty of associated professors, students, postdoctoral fellows, a planning board, affiliates and sponsors. The institute was formed as a joint effort by faculty of many universities to transcend departmental boundaries and coordinate research efforts. NECSI works closely with faculty of MIT, Harvard and Brandeis Universities. Affiliates teach and work at many other national and international locations. NECSI promotes the international community of researcher and welcomes broad participation in its activities and programs.

Content of the web site:

Evolution and ecology *(Erik Rauch, Justin Werfel, Daniel Rosenbloom, Hiroki Sayama, Marcus A. M. de Aguiar, Michel Baranger, Charles Goodnight, Les Kaufman, Yaneer Bar-Yam),* ***Networks*** *(Benjamin Shargel, Hiroki Sayama, Irving Epstein, Donald Ingber, Sui Huang, Gabriel Eichler, Temple Smith, Benjamin Lovegren de Bivort, Dan Braha, Yaneer Bar-Yam),* ***Systems Biology*** *(Benjamin Lovegren de Bivort, Gabriel Eichler, Sui Huang, Donald Ingber, and Yaneer Bar-Yam),* ***Engineering Complex Systems*** *(Dan Braha, Peyman Faratin, Mark Klein, Hiroki Sayama, and Yaneer Bar-Yam),* ***Negotiation*** *(Mark Klein, Peyman Faratin, Hiroki Sayama, Richard Metzler, Yaneer Bar-Yam),* ***Multiscale Representations*** *(Speranta Gheorghiu-Svirschevski, Richard Metzler, David Meyer, Michel Baranger, Yaneer Bar-Yam),* ***Quantitative languages*** *(Mark Smith, Yaneer Bar-Yam, William Gelbart),* ***Artificial self-replication and evolution*** *(Hiroki Sayama),* ***Environmental complexity*** *(Alice W. Davidson and Yaneer Bar-*

Yam), ***Complex Systems Perspectives on Education and the Education System*** *(Kathleen Rhoades, Linda Booth Sweeney, Jim Kaput, Miriam Bar-Yam, Yaneer Bar-Yam).*

<u>Organization</u>: OPEN2.NET (Systems Practice – Managing Complexity)

Web site(s):

http://www.open2.net/systems/index.html

From the web site:

Open2.net is the online learning portal from the Open University and the BBC.

Systems thinking enables you to grasp and manage situations of complexity and uncertainty in which there are no simple answers. It's a way of 'learning your way towards effective action' by looking at connected wholes rather than separate parts. It's sometimes called practical holism. "Systems thinking is the key literacy that we need for the future." Systems thinking leads to Systems Practice. Systems Thinking has emerged in response to the increasing complexity we now face in the world. In this section, some of the pioneers of systems thinking share their experiences and insights. We also show how contemporary systems practitioners have come to grips with some messy situations.

<u>Organization</u>: Petri Nets World

Web site(s):

http://www.informatik.uni-hamburg.de/TGI/PetriNets/

From the web site:

The purpose of the Petri Nets World is to provide a variety of online services for the international Petri Nets community. The services constitute, among other things, information on the International Conferences on Application and Theory of Petri Nets, mailing lists, bibliographies, tool databases, newsletters, and addresses. The Petri Nets Steering Committee supervises these activities, and the site is maintained by the TGI group at the University of Hamburg, Germany.

<u>Organization</u>: Prediction Company

Web site(s):

http://www.predict.com/html/introduction.html

From the web site:

The world of financial trading is changing rapidly. Market integration and consolidation, decimalization, 24 hour trading sessions, regulatory changes, online trading, rapid information dissemination - these and other forces create an ever-changing environment. This environment makes it difficult for the traditional trader or investment manager, even armed with the best in

commercial technology, to deliver consistent, positive results. Prediction Company is bringing two main forces to bear against this changing environment: world class technology and world class science. Our technology allows us to build fully automated trading systems which can handle huge amounts of data, react and make decisions based on that data and execute transactions based on those decisions - all in real time. Our science allows us to build accurate and consistent predictive models of markets and the behavior of financial instruments traded in those markets. For the last 12 years Prediction Company has been assembling a world class team of scientists, technologists and engineers. Working with our exclusive partner, UBS AG, we have built automated trading systems for a variety of markets and successfully traded those systems. We have a substantial track record with excellent results. Now we are looking to apply our technology to new markets, new instruments and new applications. If you are a scientist, technologist or software developer who is looking for an intellectual challenge with significant financial benefits you may qualify to be a member of our team. Use one of the links on the left to find out more about the company, our location and the positions we have open.

Organization: RedfishGroup

Web site(s):

http://www.redfish.com/

From the web site:

RedfishGroup is a loosely-coupled organization of complexity researchers, software developers and business professionals applying the emerging science of Complex Adaptive Systems to difficult problems in business and government. RedfishGroup was founded in 1991 by Stephen Guerin and is currently based in Santa Fe, New Mexico. We continually seek opportunities to work with other like-minded researchers and developers. Many participate in the local community of FriamGroup. RedfishGroup's 3D interactive visualizations present the dynamics of complex systems in meaningful ways. Game-like interactivity allows for exploration of the phase-space of a system as agent and environmental parameters are changed on-the-fly. Our visualization toolset can integrate with existing models or with custom Redfish-designed agent-based models. Simulation of your organization's processes via agent-based modeling can give you a birds-eye view of the workflows of your organization. A common view can drive diverse stakeholders to common understandings which allows them to move toward agreement on future actions. Coupled with our expertise in 3D visualization, solutions found in agent-based modeling exercises can move outside of the modeling group and diffuse throughout your organization and to your collaboration partners. Typical process flow on projects:

- *Clearly specify question(s) to be answered by agent-based modeling exercise. Success is critically coupled to a clear question.*
- *Collaborative exploration with domain experts to formulate model(s) of organization. This step may be expanded to field work applying ethnographic methods (see Orgviz).*
- *Develop agents to represent the heterogeneous components of your organization.*
- *Simulate agents interacting in ranges of external environments*
- *Animate the dynamics through 3D visualization.*

- *Applications of validated models*
  - *Machine Learning and Agent Optimization*
  - *Adaptive Resource Scheduling*
  - *Portfolio Management*
  - *Risk Management*
  - *Training / "flight simulators*

RedfishGroup can help you design self-organizing software systems for your organization or technical application. We leverage current complex adaptive systems research conducted at Santa Fe Institue and related institutions. Self-organizing systems are ideally suited for coordinating people, software systems and/or business processes when it is too costly, undesirable or impossible to centralize the control of the system. Self-organizing systems are often robust to unplanned failures and adaptive to changing operational environments. Contact us for a demonstration of previous implementations.

Organization: RICE Cognitive Sciences

Web site(s):

http://www.ruf.rice.edu/~cognsci/

From the web site:

Researchers in this interdisciplinary field seek to understand such mental phenomena as perception, thought, memory, the acquisition and use of language, learning, concept formation, and consciousness. Some investigators focus on relationships between brain structures and behavior, some work with computer simulation, and others work at more abstract philosophical levels.

Organization: Santa Fe Institure (SFI)

Address and web site(s):

Santa Fe Institute, 1399 Hyde Park Road, Santa Fe, NM 87501

http://www.santafe.edu/

From the web site:

The Santa Fe Institute is a private, not-for-profit, independent research and education center founded in 1984, for multidisciplinary collaborations in the physical, biological, computational, and social sciences. Understanding of complex adaptive systems is critical to addressing key environmental, technological, biological, economic, and political challenges. The Santa Fe Institute is devoted to creating a new kind of scientific research community, one emphasizing multidisciplinary collaboration in pursuit of understanding the common themes that arise in natural, artificial, and social systems. This unique scientific enterprise attempts to uncover the

mechanisms that underlie the deep simplicity present in our complex world. SFI seeks to catalyze new research activities and serve as an "institute without walls."

Organization: Swedish Morphological Society

Web site(s):

http://www.swemorph.com/

From the web site:

*The Swedish Morphological Society is a non-profit scientific organization, whose purpose is the development and dissemination of knowledge concerning the scientific use of morphological analysis, its theory and practice. This site contains articles and links on morphological analysis, its pioneer Fritz Zwicky, and on Projects where morphological analysis has been utilized. A preliminary Tutorial, "Modeling Complex Socio-Technical Systems using Morphological Analysis", is now on the tutorial page. **General Morphological analysis** was developed by Fritz Zwicky - the Swiss-American astrophysicist and aerospace scientist based at the California Institute of Technology (CalTech) - as a method for structuring and investigating the total set of relationships contained in multi-dimensional, non-quantifiable, problem complexes (Zwicky 1966, 1969). General Morphological Analysis is a method for structuring and analysing the total set of relationships contained in multi-dimensional, non-quantifiable, problem complexes. It can be used for structuring complex policy and planning issues, developing scenario and strategy laboratories, and analysing organisational and stakeholder structures.*

Organization: Swedish Morphological Society

Web site(s):

http://www.swemorph.com/

From the web site:

General Morphological Analysis is a method for structuring and analysing the total set of relationships contained in multi-dimensional, non-quantifiable, problem complexes. It can be used for structuring complex policy and planning issues, developing scenario and strategy laboratories, and analysing organisational and stakeholder structures. The Swedish Morphological Society is a non-profit scientific organization, whose purpose is the development and dissemination of knowledge concerning the scientific use of morphological analysis, its theory and practice. This site contains articles and links on morphological analysis, its pioneer Fritz Zwicky, and on Projects where morphological analysis has been utilized. A preliminary Tutorial, "Modeling Complex Socio-Technical Systems using Morphological Analysis", is now on the tutorial page.

Organization: System Dynamics Society

Web site(s):

http://www.systemdynamics.org/

From the web site:

System dynamics is a methodology for studying and managing complex feedback systems, such as one finds in business and other social systems. In fact it has been used to address practically every sort of feedback system. While the word system has been applied to all sorts of situations, feedback is the differentiating descriptor here. Feedback refers to the situation of X affecting Y and Y in turn affecting X perhaps through a chain of causes and effects. One cannot study the link between X and Y and, independently, the link between Y and X and predict how the system will behave. Only the study of the whole system as a feedback system will lead to correct results. The methodology:

- *identifies a problem*
- *develops a dynamic hypothesis explaining the cause of the problem*
- *builds a computer simulation model of the system at the root of the problem*
- *tests the model to be certain that it reproduces the behavior seen in the real world*
- *devises and tests in the model alternative policies that alleviate the problem*
- *implements this solution*

Rarely is one able to proceed through these steps without reviewing and refining an earlier step. For instance, the first problem identified may be only a symptom of a still greater problem. The field developed initially from the work of Jay W. Forrester. His seminal book Industrial Dynamics (Forrester 1961) is still a significant statement of philosophy and methodology in the field. Since its publication, the span of applications has grown extensively and now encompasses work in: corporate planning and policy design, public management and policy, biological and medical modeling, energy and the environment, theory development in the natural and social sciences, dynamic decision making and complex nonlinear dynamics.

Organization: System of Systems Engineering

Web site(s):

http://www.sosece.org/

From the web site:

- ***Vision Statement****: The System of Systems Engineering Center of Excellence (SoSECE) is the Center of Excellence for System of Systems (SoS) Engineering solutions and serves as a resource for developing, fielding, and supporting SoS solutions.*
- ***Mission Statement****: The mission of the System of Systems Engineering Center of Excellence (SoSECE) is to advance the development, evolution, practice, and application of the System of Systems (SoS) Engineering discipline across complex systems from individual system to enterprise wide designs.*

- ***SoSECE Objectives****: Develop and evolve the System of Systems (SoS) Engineering methodology; Expand the SoS Engineering Body of Knowledge (BoK) to include studies, experiments, analysis, and relevant applications; Provide access to the SoS Engineering BoK; Support organizations that have complex systems problems - but are not currently applying SoS Engineering - in an effort to achieve SoS solutions; Support organizations applying or seeking SoS Engineering to: Build SoS Engineering expertise through application - conduct development, demonstrations, tests, validation, and verification; Educate and train industry and government professionals in the SoS Engineering practices and applications.*
- ***SoSECE Charter****: Develop, demonstrate, and apply methods of System of Systems (SoS) Engineering; Develop criteria for deriving metasystem-level metrics of the SoS that support the traditional systems engineering process; Identify/customize state-of-the-art analytic and decisional tools for SoS Engineering; Collect relevant best practices and lessons learned, and make them available; Form an Executive Steering Board comprised of technical experts to advise and guide the System of Systems Engineering Center of Excellence (SoSECE)*

Organization: Swarm Development Group (Wiki)

Web site(s):

http://www.swarm.org/wiki/Main_Page#Swarm_Development_Group

Organization: The Center for Complexity and Change

Web site(s):

http://ccc.open.ac.uk/

From the web site:

The Centre for Complexity and Change (CCC) links the work of three disciplines in the Open University's Technology Faculty, each with an international reputation for excellence in teaching and research:

- *Systems*
- *Development Policy & Practice*
- *Technology Management*

Members of the Centre share a commitment to interdisciplinary and systemic approaches to the study of complexity and change, especially in the management of technologies, organizations, the environment and sustainable development in all parts of the world. Their work is particularly concerned with the impact of technological activities, the development of new technologies, and the management of interventions, including forecasting and assessment, regulation and innovation. Their emphasis is on taking a holistic view of situations, by considering the changing use of technology within its social, economic, cultural and institutional context. The aim of the Centre is to improve the understanding of complex situations involving technology so as to aid the decision making of people faced with change.

Organization: The Center for Complexity Research

Web site(s):

http://www.liv.ac.uk/ccr/2005_conf/index.htm

From the web site:

The Centre for Complexity Research is a unique interdisciplinary centre created to promote complexity sciences and applications in the University of Liverpool, Merseyside region, and beyond.

Organization: The Complexity & Artificial Life Research Concept for Self-Organizing Systems (CALRESCO)

Web site(s):

http://www.calresco.org/index.htm

From the web site:

CALResCo was set up in 1996 to fulfil a perceived need on the Internet to integrate the information about Complex Systems, in all its various guises, and present it in a way useful to both beginners and those already familiar with one or more of the fields. As an educational resource it provides comprehensive links to tutorial materials around the world, as well as to more technical papers and resources. A large part of our efforts is dedicated to raising familiarity about the concepts of Complex Systems within the traditional scientific and human disciplines, and to this end we present interdisciplinary papers introducing and relating these concepts to more familiar subjects and situations. Many of the fields that we consider go back many years, yet it is only with the advent of cheap computer resources that we have seen their blossoming into mainstream research. Simulations and iterations on a computer are the essence of Complex Systems research, and allow us to explore the infinite space of possible systems in a way not previously possible. As we enter the third millennium we will see the value of this approach, as a way to analyse and understand systems too complex for Newtonian analysis and too simple for Statistical averaging - in other words, Life.Our work considers many aspects of complex systems, from quantum theory and cosmology, through biological evolution to psychology and social systems. We also devote attention to the arts, humanities, parapsychology and the mystical realms, where this proves useful and scientifically valid. The team members all pursue their own specialised interests as well as pooling ideas where useful. We are looking chiefly to make connections between behaviours in these wider fields and the findings of those ALife and Complexity researchers doing primary work in the specialist fields. I personally have a particular interest in attractor theory and the dynamics of systems at the edge of chaos. I am looking to develop sets of criteria with which to explain self-organization, and hopefully to illuminate methods of control and prediction that are commonly applicable over a wide range of fields, inorganic, organic and cultural. My current work concentrates upon the incorporation of values into complexity science, and in the use of systems concepts and synergetic thinking to develop sustainable and diversity related new metaperspectives or worldviews suitable for a multicultural world. My philosophy is transdisciplinary, but biased towards scientific areas and

to the search for a rigorous and quantitative theory of complex systems, which will allow future predictive applications. I follow the paradigms being developed and espoused by the Santa Fe Institute, particularly in the realms of Boolean and NKC networks with their attractor and co-evolutionary fitness spaces. One area of special interest to me is in those areas of state space not currently being explored and the new concepts we may need to approach these creatively.

Some of the Questions for which we seek answers:

- *Explanations of wayward, one-off events and how they relate to chaotic concepts.*
- *Why the whole is greater than the sum of the parts, i.e. the meaning of emergence.*
- *Physical, Intellectual, Emotional balance criteria for social optimisation.*
- *What is reality, multidimensional models and their relationship to non-material structures.*
- *Ethics of co-operation and interaction, i.e. the understanding of synergic possibility.*
- *Dynamics of non-chaotic evolving systems without fixed attractors or state cycles*
- *Using edge-of-chaos not preventing it - managing ill-behaved systems*
- *Constraints on state space, and escaping local optima into unexplored state space*
- *Transient effects of perturbation and instability on social systems*
- *Scale independent properties common to all systems*
- *Relevance of holographic transforms within the brain as a parallel processing methodology*
- *The possibility of fact independent consciousness and alternative realities*
- *Intrinsic meaning of bifurcation and choice, i.e. autonomy and teleology*
- *Field theories of complex systems and their relationship to quantum field concepts*
- *Consciousness levels as a function of complexity and their criteria*
- *Relativity of the concept of self and its possible underlying invalidity*

Our world view is extensively relativistic, concentrating on probability, view transformations, and the meaning of connectedness, at both quantum and macro levels. I concentrate on dynamic science, within the paradigm of hard science but without the conceptual restrictions that often constrain the viewpoints of traditional science. I'm also interested in the application of complexity research to political and social issues and for improving the quality of life throughout the world . This requires I think an evolutionary view of all things, a bottom up synthesis merging with a top down holism.

<u>Organization</u>: The Complexity & Management Center

Web site(s):

http://www.herts.ac.uk/business/centres/cmc/

From the web site:

The Complexity and Management Centre of the Business School of the University of Hertfordshire was set up in 1995 to create links between academic work and organizational practice using a complexity perspective, in which the inevitable paradoxes and ambiguities of organizational life are not finally resolved but held in creative tension. This perspective draws on insights into evolutionary theory emerging in the natural sciences, strands of social constructionist thought in the social sciences and various psychological understandings of the dynamics at work in networks of human relationship. The Complexity and Management Centre seeks new ways of working with these ideas, emphasizing the self-organizing potential of ordinary conversation in which people reflect together on their personal experiences.

Organization: The Complexity Society

Web site and address:

http://www.complexity-society.com/

Business School, University of Hertfordshire,UK.

From the web site:

The Complexity Society provides a focal point for people in the UK interested in complexity. It is a community that uses complexity science to rethink and reinterpret all aspects of the world in which we live and work. Its core values are OPENNESS, EQUALITY and DIVERSITY. Open to all, open to ideas, open in process and activities. Equality, egalitarian, non-hierarchical, participative. Diverse, connecting and embracing a wide range of views, respecting differences. The society objectives are to promote the theory of complexity in education, government, the health service and business as well as the beneficial application of complexity in a wide variety of social, economic, scientific and technological contexts such as sources of competitive advantage, business clusters and knowledge management. Complexity includes ideas such as complex adaptive systems, self-organisation, co-evolution, agent based computer models, chaos, networks, emergence and fractals.

Organization: The Institute for Modeling Complexity

Web site(s):

http://www.modelingcomplexity.net/

From the web site:

The Institute for Modeling Complexity was created by faculty members at Mesa State College, in Grand Junction, Colorado, but has grown into an inter-institutional and inter-disciplinary group of scholars and teachers interested in the study of complex systems, with particular interest in the modeling processes used to explore complexity. We are currently supported by the Advanced Learning Center at Mesa State College, which offers hands-on project-based education to high school and college students through the pilot course simThinking: Modeling the Social and Natural World.

Organization: The Open Network of Centres of Excellence in Complex Systems (ONCE-CS)

Web site(s):

http://complexsystems.lri.fr/Portal/tiki-index.php

From the web site:

The new science of Complex System addresses the need to master the increasing complexity we see in natural and social systems. Examples include the human and new treatments for disease, managing the Internet, public administration, and business. This new science will revolutionise our world, causing irresistible changes. It is essential that Europe is a world leader I this science if it is to remain competitive on the world stage. ONCE-CS stands for Open Network of Centres of Excellence in Complex Systems. It is funded by the European Commission by the FET unit (Future and Emerging technology) of the IST (Information Society Technology) priority of Framework 6. It will continue the work of the Exystence network (5thPCRdT). At the end of Once-CS mission, all the content of this site will become part of the European Complex System Society that will continue to host Complex Systems projects. The purpose of ONCE-CS is to strengthen European research in complex systems, and to assist people in business and public services to use the new science with the following activities.

Organization: The Open University

Web site(s):

http://technology.open.ac.uk/ccc/csrc/

From the web site:

Aim: To establish the Open University as an international centre of excellence and expertise in complexity science research. EXPLORATION: To carry out, encourage and assist interdisciplinary research and collaborative explorations on complexity science within the University, the UK and internationally. DESIGN: To create imaginative and robust models using the latest concepts and techniques in such areas as organisations and management, computer simulations, traffic systems and environmental systems . INNOVATION: To encourage creative and highly innovative research while working closely with other research groups, interested individuals and UK and international organisations. IMPLEMENTATION: To promote and apply the theoretical and practical applications of complexity science with seminars, conferences, networking, publications and consultancy.

Organization: Theory of Computation Group (MIT)

Web site(s):

http://theory.csail.mit.edu/

From the web site:

The Theory of Computation (TOC) Group is part of the MIT Computer Science and Artificial Intelligence Laboratory. We're one of the largest theoretical computer science research groups in the world, and we have faculty, students, and visitors from both the Department of Electrical Engineering and Computer Science and the Department of Mathematics. Research Groups are:

- *Algorithms*
- *Computation and Biology*
- *Distributed Systems*
- *Semantics*
- *Complexity Theory*
- *Cryptography and Information Security*
- *Numerical Analysis and Scientific Computing*
- *Supercomputing Technologies*

Organization: UCL CoMPLEX

Web site(s):

http://www.ucl.ac.uk/CoMPLEX/

From the web site:

CoMPLEX brings life and medical scientists together with mathematicians, physical scientists, computer scientists and engineers to tackle the challenges arising from complexity in biology and medicine. CoMPLEX is the first truly inter-disciplinary centre of its kind in the UK. It provides a forum for inter-disciplinary teaching and research that is unique within the UK scientific community. There are now more than 125 members spread across 25 UCL departments, with collaborative projects where biologists and physical scientists are tackling problems of common interest. Launched in 1998 as a virtual centre, CoMPLEX now operates from new offices at Wolfson House (Wolfson House map), close to the main UCL site. This provides an active and intellectually stimulating environment for students on the CoMPLEX PhD program, for inter-disciplinary seminars and workshops and for research project meetings. In 2003 CoMPLEX was awarded funding by the EPSRC for the Doctoral Training Centre as part of the EPSRC's Life Sciences Interface Programme. This funding, with further funding from the MRC and UCL currently enables CoMPLEX to fund 14 students per year on the CoMPLEX 4 year PhD programme. Eight Doctoral Training Centres are funded by the EPSRC. CoMPLEX's PhD students are involved in a range of inter-disciplinary research projects that involve collaborations between supervisors drawn from Life Science, Mathematics, Engineering, Computer Science and Physics departments. In addition CoMPLEX hosts a number of interdisciplinary teams, including the DTI Beacon Project Team which are engaged in leading life science research. Follow this link to see details of CoMPLEX students' research and publications. CoMPLEX runs a series of seminars, which are held monthly and cover a range of topics. The Journal club meets fortnightly at Wolfson House for a paper and discussion.

6 Projects

Project: Autonomic Computing

Web site(s):

http://www-03.ibm.com/autonomic/

From the web site:

Autonomic computing systems have the ability to manage themselves and dynamically adapt to change in accordance with business policies and objectives, enabling computers to identify and correct problems often before they are noticed by IT personnel. IBM is delivering Self-Managing Autonomic Technology solutions to help companies transform their IT infrastructures into more resilient, responsive, efficient, and secure systems that deliver significant value today. For many, autonomic computing is likely to conjure up the vision IBM first introduced to the industry almost four years ago. That vision has now translated to a comprehensive set of services, software, technology mark program, and industry participation that clearly has brought autonomic computing to "center stage." Industry leaders are now actively participating with IBM to make self-managing IT systems a reality, and clients and Business Partners are seeing self-managing autonomic technology solutions deliver significant, quantifiable value today.

From Wikipedia web site (Wikipedia, 2006):

Autonomic Computing is an initiative started by IBM in 2001. Its ultimate aim is to create self-managing computer systems to overcome their rapidly growing complexity and to enable their further growth.

Contact:

actool@us.ibm.com

Project: Biology-Inspired techniques for Self-Organization in dynamic Networks (BISON)

Web site(s):

http://www.cs.unibo.it/bison/

From the web site:

BISON is a three-year Shared-Cost RTD Project (IST-2001-38923) funded by the Future & Emerging Technologies initiative of the Information Society Technologies Programme of the European Commission. The project runs from January 2003 until April 2006. The complexity of modern Network Information Systems (NIS) has reached a level that puts them beyond our ability to deploy, manage and keep functioning correctly through traditional techniques. Part of the problem is due to the sheer size that these systems may reach with millions of users and millions of interconnected devices. The other aspect of the problem is due to the extremely complex

interactions that may result among components even when their numbers are modest. Our current understanding of these systems is such that minor perturbations in some remote corner of the system will often have unforeseen, and at times catastrophic, global repercussions. In addition to being fragile, many situations arising from the highly dynamic environment in which they are deployed require manual intervention to keep NIS functioning. What is required is a paradigm shift in confronting the complexity explosion problem to enable building robust NIS that are self-organizing and self-repairing. BISON draws inspiration from biological processes and mechanisms to develop techniques and tools for building robust, self-organizing and adaptive NIS as ensembles of autonomous agents. What renders this approach particularly attractive from a dynamic network perspective is that global properties like adaptation, self-organization and robustness are achieved without explicitly programming them into the individual artificial agents. Yet, given large ensembles of agents, the global behavior is surprisingly adaptive and can cope with arbitrary initial conditions, unforeseen scenarios, variations in the environment or presence of deviant agents. This represents a radical shift from traditional algorithmic techniques to that of obtaining the desired system properties as a result of emergent behavior that often involves evolution, adaptation, or learning. BISON explores the use of ideas derived from complex adaptive systems (CAS) to enable the construction of robust and self-organizing information systems for deployment in highly dynamic network environments. We cast solutions to important problems arising in overlay networks and mobile ad-hoc networks as desirable global properties that systems should exhibit. We then search for CAS which can bring about these global properties. A longer-term goal of BISON is to systematize this process --- to develop a coherent set of heuristics that can guide the search for CAS giving a desired global behavior.

Contact:

Project Coordinator: Prof. Ozalp Babaoglu, University of Bologna, Department of Computer Science, Mura Anteo Zamboni, 7, 40127 Bologna, Italy. Tel: +39 051 2094504, Fax:+39 051 2094510

Comments from DRDC reviewer:

Many publications could be found in 2006 at: http://www.cs.unibo.it/bison/progress/list.shtml

Project: Complexity and Capacity Analysis (COCA)

Web site(s):

http://www.eurocontrol.int/eec/public/standard_page/NCD_coca.html

From the web site:

The principle goal of the COCA (Complexity and Capacity Analysis) project is to provide some relevant, measurable, and meaningful indicators to evaluate the intrinsic difficulty of the ATM tasks (Air Traffic Management) in the context of the airspace concerned. Description: Analysis of the relationship between complexity, controller workload, sector type and capacity through comparison of indicators between different centres of control.

Contact:

Geraldine Flynn (geraldine.flynn@eurocontrol.int)

COCA Project Manager

Project: Decentralized Metaheuristics (Decent)

Web site(s):

http://www.ercim.org/publication/Ercim_News/enw64/alba.html

From the web site:

The project 'Decent' (Decentralized Metaheuristics) is developing new swarm-based metaheuristics in which a decentralized design leads to emergent phenomena. These are not only important for solving complex problems, but are suitable for parallel execution in computing grids and multi-task hardware platforms. Metaheuristics, such as evolutionary algorithms (EA), ant colony optimization (ACO), simulated annealing (SA) and particle swarm optimization (PSO), are methods that can be applied successfully to almost all optimization problems. For many hard tasks in a huge variety of areas, these algorithms are considered to be the state-of-the-art methods; these areas include engineering applications, bioinformatics, telecommunications, logistics and business. Due to their practical importance and the need to solve large real-world instances of hard problems, parallel algorithms have been proposed for most metaheuristics. However, most approaches do not utilize the full potential of parallel execution because of their synchronicity and execution on clusters of homogeneous machines. All this makes it difficult to apply them to interesting parallel systems such as dynamically reconfigurable hardware (eg FPGAs) and large heterogeneous networks (computational grids). In the 'Decent' project, strictly decentralized versions of metaheuristics that do not suffer from the restrictions of standard parallel/distributed metaheuristics are developed. 'Decent' is a two-year joint project between researchers from the University of Málaga (Spain) and the University of Leipzig (Germany). The project is funded by MECD (Ministerio de Educación y Ciencia, Spain) and DAAD (German Academic Exchange Service) within the 'Spain-Germany Integrated Actions' framework (HA2004-0008). The main focus of the project is on decentralized algorithms that are suitable for dynamically changing heterogeneous networks, as mobile ad hoc (and sensor) networks and dynamically reconfigurable computing systems. One main goal is to investigate the emergent properties of such decentralized swarm-based algorithms, not found in the separate behaviour of their components. This is expected to have a significant impact both in the field of advanced algorithms and in applications. This is particularly the case for complex problems arising in telecommunications (routing, coding, broadcasting etc) and bioinformatics (DNA fragment assembly, protein structure etc).

Project: Dynamically Evolving, Large-scale Information Systems (DELIS)

Web site(s):

http://delis.upb.de/

From the web site:

DELIS is an Integrated European Project founded by the "Complex Systems" Proactive Initiative within the Sixth Framework Programm. Information Systems like the physical Internet, the World Wide Web, telephone networks, mobile ad-hoc networks, or peer-to-peer networks have reached a level that puts them beyond our ability to deploy them, manage them, and keep them functioning correctly through traditional techniques. Reasons for this are their sheer size with millions of users and interconnected devices and their dynamics; they evolve dynamically over time, i.e., components change or are removed or inserted permanently. For such systems, we have to abandon the goal of global optimality. Within DELIS, we therefore concentrate on developing self-regulating and self-repairing mechanisms that, on the one hand, are decentralized, scalable, and adapt to changes in their environments. On the other hand, these decentralized mechanisms have to lead to a globally acceptable behavior, avoiding undesirable ortd unstable situations. We believe that the combination of insights from statistical physics, market mechanisms, and biological and social behavior with advanced algorithmic research in Computer Science is the right combination of expertise necessary to develop methods, techniques, and tools to cope with such challenges imposed by large scale information systems, and to contribute to the world-wide effort in complex systems research towards understanding the principles necessary to manage such systems.

Project: ECHO (ECHO)

Web site(s):

http://www.santafe.edu/projects/echo/

From the web site:

Echo is a simulation tool developed to investigate mechanisms which regulate diversity and information-processing in systems comprised of many interacting adaptive agents, or complex adaptive systems (CAS). Echo agents interact via combat, trade and mating and develop strategies to ensure survival in resource-limited environments. Individual genotypes encode rules for interactions. In a typical simulation, populations of these genomes evolve interaction networks which regulate the flow of resources. Resulting networks resemble species communities in ecological systems. Flexibly defined parameters and initial conditions enable researchers to conduct a range of "what-if" experiments.

Contact:

John Holland, Santa Fe Institute, 1399 Hyde Park Road, Santa Fe, NM 87501

http://www.santafe.edu/

Project: EMBIO Project

Web site(s):

http://www-embio.ch.cam.ac.uk/main.html

From the web site:

Biomolecular systems exhibit spontaneous self-organisation that is critical to their function. Examples are protein folding and the self-assembly of membranes. The project aims to develop mathematical and computational approaches primarily to identify the poorly understood principles of this phenomenon. This will provide a basis for modelling of this fundamental property of complex biomolecular systems and will therefore be of great importance to biology, medicine and biotechnology. The project is funded by the European Commision in the Sixth Framework programme within "New and emerging science and technology NEST - PATHFINDER" research area. The consortium consists of eight Universities (http://www-embio.ch.cam.ac.uk/consortium/index.html) from six countries and coordinated by Cambridge University.

Project: The TRACER Project

Web site(s):

http://tracer.lcc.uma.es/

From the web site:

TRACER is an MCyT and FEDER funded project aimed at performing research in computer science with roughly two foci: a. Making advances in modern optimization and search techniques; b. Solving complex problems at a higher efficiency and accuracy TRACER is intended to provide concrete results to the community: 1. Software facilities for programmers; 2. An Internet front end for non-specialized researcher; 3. A web site with problems descriptions and detail; 4. A network of thematic mini-web sites on specialized research domains

Contacts:

TRACER is a coordinated research project in which 5 (five) groups are cooperating to solve complex problems with modern optimization, search and learning tools. The participating groups are: 1. Researchers from the GISUM group at the university of Málaga (coordinator: http://neo.lcc.uma.es/); 2. Researchers from the Parallel Computing Group at the univ. of La Laguna (http://www.tracer.ull.es/); 3. Researchers from the Theoretical Computer Science at the UPC in Barcelona (http://tracer.lsi.upc.es/); 4. Researchers from the ScaLab group at the univ. Carlos III in Madrid (http://tracer.uc3m.es/); 5. Researchers from the university of Extremadura (http://tracer.unex.es/).

Project: Urban Traffic Control (UTC-NG)

Web site(s):

http://www.dsg.cs.tcd.ie/index.php?category_id=294

From the web site:

Building on the Distributed Systems Group's experience in mobile distributed computing and wireless communication, this project will explore the design of next generation Urban Traffic Control (UTC) systems. Existing traffic control systems utilise a relatively small amount of

information. This information is typically provided by sensors at traffic junctions together with traffic cameras providing journey-time estimations. In the coming years, an increase in the number of available of sensors/actuator's will increase the amount of information available to UTC systems. Some examples of these sensors/actuators include GPS devices, wireless communication, electronic signs. The increased availability of such information will have a significant impact on next generation UTCs. Future UTCs will be able to respond in real-time to actual traffic conditions both locally and globally across the system. In addition, this information could be used to allow the creation of new applications such as smart roads, in-car guides, etc. This project will undertake the design of a next generation UTC system capable of exploiting the available information to support existing and to build new traffic-related applications. Modeling this new and sensor rich information will be an important part of the design. Communicating the relevant information to the appropriate end user will be another key design issue. The UTC-NG project is part of the Centre for Transportation Research and Innovation for People (TRIP), a multidisciplinary research centre, funded under the Programme for Research in Third Level Institutions (PRTLI) administered by the Higher Education Authority (HEA) of Ireland.

Contacts:

Vinny Cahill, Phone: +353-1-608-1795, Room: ORI F27, http://www.dsg.cs.tcd.ie/~vjcahill/ , Vinny.Cahill-at-cs.tcd.ie

Raymond Cunningham, Phone: +353-1-608-2666, Room: Lloyd 015, http://www.dsg.cs.tcd.ie/~rcnnnghm/, Raymond.Cunningham-at-cs.tcd.ie

Project: World-Wide-Mind Project (W2Mind)

Web site(s):

http://w2mind.org/

From the web site:

This work proposes that the construction of advanced artificial minds may be too difficult for any single laboratory to complete. At the moment, no easy system exists whereby a working mind can be made from the components of two or more laboratories. This system aims to change that, and accelerate the growth of Artificial Intelligence, once the requirement that a single laboratory understand the entire system is removed.

Contacts:

Dublin City University:

Mark Humphrys (http://computing.dcu.ie/~humphrys/)

Ray Walshe (http://computing.dcu.ie/~ray/)

Dave O'Connor (http://www.swearing.org/)

Dublin Institute of Technology:

Ciarán O'Leary (http://www.comp.dit.ie/coleary/)

Comments from DRDC reviewer:

The project was started in 2001 by Dr Mark Humphrys at Dublin City University. The main goal was to facilitate the integration of the many diverse components of agent minds into whole minds.

Related papers

Papers related this project could be found in 2006 at: http://w2mind.org/publications.html

7 Journals

Journal: Adaptive Behavior

Publisher:

Published by SAGE Publications (http://www.sagepub.co.uk/).

Web site(s):

http://www.isab.org/journal/toc.php

From the web site:

Adaptive Behavior, published by Sage Publications, is the premier international journal for research on adaptive behavior in animals and autonomous artificial systems. For over 10 years it has offered ethologists, psychologists, behavioral ecologists, computer scientists, and robotics researchers a forum for discussing new findings and comparing insights and approaches across disciplines. Adaptive Behavior explores mechanisms, organizational principles, and architectures for generating action in environments, as expressed in computational, physical, or mathematical models.

Journal: Advances in Complex Systems

Publisher:

HERMES Science Publications (1998-2000).

Web site(s):

http://www.tbi.univie.ac.at/~studla/ACS/AimsScopes.html

From the web site:

Advances in Complex Systems aims to provide a unique medium of communication for multidisciplinary approaches, either empirical or theoretical, to the study of complex systems in such diverse fields as biology, physics, engineering, economics, cognitive science and social sciences, so as to promote the cross-fertilization of ideas among all the scientific disciplines having to deal with their own complex systems. By complex system, it is meant a system comprised of a (usually large) number of (usually strongly) interacting entities, processes, or agents, the understanding of which requires the development, or the use of, new scientific tools, nonlinear models, out-of equilibrium descriptions and computer simulations. Understanding the behavior of the whole from the behavior of its constituent units is a recurring theme in modern science, and is the central topic of Advances in Complex Systems. Papers suitable for publication in Advances in Complex Systems should deal with complex systems, from an empirical or theoretical viewpoint, or both, in biology, physics, engineering, economics, cognitive science and

social sciences. This list is not exhaustive. One important component of the papers should be their cross-disciplinary approach or perspective.

Journal: Air & Space Power Journal

Publisher:

Airpower Research Institute (ARI), part of the US Air Force's College of Aerospace Doctrine, Research and Education (CADRE) at Maxwell Air Force Base, Alabama, USA.

Web site(s):

http://www.airpower.maxwell.af.mil/airchronicles/

From the web site:

ASPJ and its COJ companion are the professional journal of the US Air Force and the leading forum for worldwide air and space power thought. We've published the English language ASPJ since 1947. Previous names of the publication include: Aerospace Power Journal, Airpower Journal, and Air University Review. The Spanish and Portuguese ASPJ editions have provided outreach to international military readers since 1949. The Arabic and French language ASPJ editions commenced publication in 2005. The English language ASPJ promotes air and space power professional dialogue among USAF members as well as other English-speaking militaries around the world in order to foster intellectual and professional development. The other ASPJ language editions serve the same professional needs for air forces, armies, and navies in Latin America, Africa, the Middle East, Asia, and Europe. COJ serves all these audiences.

Journal: Artificial Life

Publisher:

MIT Press, Mark A. Bedau, Editor

Web site(s):

http://mitpress.mit.edu/catalog/item/default.asp?ttype=4&tid=41

http://www.mitpressjournals.org/loi/artl?cookieSet=1

From the web site:

Artificial Life is devoted to a new discipline that investigates the scientific, engineering, philosophical, and social issues involved in our rapidly increasing technological ability to synthesize life-like behaviors from scratch in computers, machines, molecules, and other alternative media. By extending the horizons of empirical research in biology beyond the territory currently circumscribed by life-as-we-know-it, the study of artificial life gives us access to the domain of life-as-it-could-be. Relevant topics span the hierarchy of biological organization,

including studies of the origin of life, self-assembly, growth and development, evolutionary and ecological dynamics, animal and robot behavior, social organization, and cultural evolution.

Journal: Autonomous Agents and Multi-Agent Systems

Publishers:

Springer Netherlands

Web site(s):

http://www.springerlink.com/(juzz3r453y3nnq55cnussv45)/app/home/journal.asp?referrer=parent&backto=linkingpublicationresults,1:102852,1

Journal: Chaos

Publisher:

Chaos Editorial Office, American Institute of Physics, Suite 1NO1, 2 Huntington Quadrangle, Melville, NY 11747-4502, USA, Telephone: 516-576-2403, Fax: 516-576-2223, E-mail: chaos@aip.org

Web site(s):

http://chaos.aip.org/chaos/staff.jsp

From the web site:

Chaos is a quarterly journal published by the American Institute of Physics and devoted to increasing the understanding of nonlinear phenomena and describing the manifestations in a manner comprehensible to researchers from a broad spectrum of disciplines. The now celebrated example of period doubling illustrates the crucial importance of transferring the developments in our understanding of nonlinear phenomena, wherever these developments occur, to other disciplines. The excitement and challenge of the journal, Chaos: An Interdisciplinary Journal of Nonlinear Science, lie in its interdisciplinary character and its firm committment to communicating the most recent developments in nonlinear science to the research community at large. We welcome contributions from physics, mathematics, chemistry, biology, engineering, economics, and social sciences, as well as other disciplines in which inherently nonlinear phenomena are of interest and importance. Further, we always seek a balance among the methods of computation, theory, and experiment, to reflect properly the tripartite methodology which has proved essential to the progress of nonlinear science. Finally, Chaos has grown to be truly international in character, again mirroring the field itself.

Journal: Cognitive Systems Research

Publisher:

Elsevier

Web site(s):

http://www.sciencedirect.com/science?_ob=JournalURL&_cdi=6595&_auth=y&_acct=C000056973&_version=1&_urlVersion=0&_userid=2337731&md5=6f99537d9ad1a5f6f4e5c83a0fae9ac0

Journal: Complex Systems

Publisher:

Complex Systems Publications, Inc., P.O. Box 6149, Champaign, IL 61826, USA

Web site(s):

http://www.complex-systems.com/

From the web site:

Complex Systems was founded by Stephen Wolfram in 1987 to provide a publication forum for the new field of complex systems research. As the premier journal in the field, Complex Systems has had the privilege of publishing many of the most important papers in the field, contributing to the growth of complex systems research for more than a decade. Complex Systems has developed a uniquely broad base of readers and contributors from academia, industry, government, and the general public in 40 countries around the world. The topics of research covered by Complex Systems span a diverse array of fields including mathematics, physics, computer science, and biology.

Journal: Complexity

Publisher:

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Web site(s):

http://www3.interscience.wiley.com/cgi-bin/jhome/38804

From the web site:

Complexity is a bi-monthly, cross-disciplinary journal focusing on the rapidly expanding science of complex adaptive systems. The purpose of the journal is to advance the science of complexity. Articles may deal with such methodological themes as chaos, genetic algorithms, cellular automata, neural networks, and evolutionary game theory. Papers treating applications in any area of natural science or human endeavor are welcome, and especially encouraged are papers integrating conceptual themes and applications that cross traditional disciplinary boundaries. Complexity is not meant to serve as a forum for speculation and vague analogies between words like "chaos," "self-organization," and "emergence" that are often used in completely different ways in science and in daily life..

Journal: Complexity International

Publisher:

Monash University

Web site(s):

http://journal-ci.csse.monash.edu.au/

From the web site:

Complexity International is a refereed journal for scientific papers dealing with any area of complex systems research. The theme of the journal is the field of complex systems, the generation of complex behaviour from the interaction of multiple parallel processes. Relevant topics include (but are not restricted to): artificial life, cellular automata, chaos theory, control theory, evolutionary programming, fractals, genetic algorithms, information systems, neural networks, non-linear dynamics, parallel computation. Papers dealing with applications of these topics (for example, to biology, economics, epidemiology, sociology) are also encouraged.

Journal: Computational Complexity

Publisher:

Birkhäuser Basel

Web site(s):

http://www.springer.com/sgw/cda/frontpage/0,11855,5-40100-70-1176553-0,00.html

From the web site:

Computational Complexity (CC) presents outstanding research in computational complexity. Its subject is at the interface between mathematics and theoretical computer science, with a clear mathematical profile and strictly mathematical format. The central topics are: Models of computation, complexity bounds, complexity classes, trade-off result: for: sequential and parallel computation, «general» (Boolean) and «structured» computation, deterministic, probabilistic, and nondeterministic computation. Specific areas of concentration include: structure of complexity classes, algebraic complexity, cryptography, interactive proofs. Complexity issues in: computational geometry, robotics, and motion planning, learning theory, number theory, logic, combinatorial optimization and approximate solutions, and distributed computing.

Journal: Cybernetics & Human Knowing

Publisher:

The editor is Søren Brier, Dept. of Economics and Natural Resources, Unit of Methods and Project Work, Rolighedsvej 23 grd. floor, DK-1958 Frederiksberg C, Copenhagen, DENMARK. The publisher is Imprint Academic.

Web site(s):

http://www.imprint.co.uk/C&HK/cyber.htm

From the web site:

The journal is devoted to the new understandings of self-organizing processes of information in human knowing that have arisen through the cybernetics of cybernetics, or second order cybernetics and its relation and relevance to other interdisciplinary approaches such as semiotics (cybersemiotics). This new development within cybernetics is a nondisciplinary approach. Through the concept of self-reference it tries to explore: the meaning of cognition and communication; our understanding of organization and information in human, artificial and natural systems; and our understanding of understanding within the natural and social sciences, humanities, information and library science, and in social practices as design, education, organisation, teaching, therapy, art, management and politics.

Journal: Dynamical Psychology

Publisher:

Editor: Ben Goertzel, Novamente LLC/ Biomind LLC / AGIRI, 14409 Oakvale St., Rockville MD 20853, (ben@goertzel.org)

Web site(s):

http://www.goertzel.org/dynapsyc/dynapsyc.html

From the web site:

While the scope of DynaPsych is broad, certain areas are of particular interest to the editors. These include, but are not limited to: nonlinear dynamics and complexity science, used to provide innovative analyses of psychological data; construct computational models which emulate the behavior of psychological systems; consciousness viewed as a process dynamical system -- from any perspective, be it neural networks, abstract algebra, Buddhism, Zoroastrianism or transpersonal psychology; the mental construction of reality, viewed from social, psychophysical, complex-systems and neurophysiological perspectives; connections between different areas of mind science -- e.g. psychophysics and learning theory, quantum physics and psychology, neurobiology and phenomenology, cognitive and transpersonal models of consciousness.

Journal: Dynamical Systems

Publisher:

Published By: Taylor & Francis

Web site(s):

http://www.tandf.co.uk/journals/titles/14689367.asp

From the web site:

The primary goal of Dynamical Systems: An International Journal (founded as Dynamics and Stability of Systems) is to act as a forum for communication across all branches of modern dynamical systems, and especially to facilitate interaction between theory and applications. This journal aims to publish high quality research articles in the theory and applications of dynamical systems, especially (but not exclusively) nonlinear systems. Advances in the following topics will be addressed by the journal: Differential equations, Bifurcation theory, Hamiltonian and Lagrangian dynamics, Hyperbolic dynamics, Ergodic theory, Topological and smooth dynamics, Random dynamical systems, Applications in technology, engineering and natural and life sciences

Journal: Ecological Complexity

Publisher:

Elsevier, Customer Service Department, 6277 Sea Harbor Drive, Orlando, FL 32887-4800 USA, Email: usjcs@elsevier.com, Customers Outside US: Tel: +1 (407) 345-4020, Fax: +1 (407) 363-1354.

Web site(s):

http://www.elsevier.com/wps/find/journaldescription.cws_home/701873/description#description

From the web site:

Ecological Complexity is an international journal devoted to the publication of high quality, peer-reviewed articles on all aspects of biocomplexity in the environment, theoretical ecology, and special issues on topics of current interest. The scope of the journal is wide and interdisciplinary with an integrated and quantitative approach. The journal particularly encourages submission of papers that integrate natural and social processes at appropriately broad spatio-temporal scales.

Journal: Emergence: Complexity & Organization (E:CO)

Publisher:

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Web site(s):

http://emergence.org/

From the web site:

Emergence: Complexity & Organization (E:CO) is an international and interdisciplinary conversation about human organizations as complex systems and the implications of complexity science for those organizations. With a unique format blending the integrity of academic inquiry and the impact of business practice, E:CO integrates multiple perspectives in management theory, research, practice and education. E:CO is a quarterly journal published in print and online by The Complexity Society, the Institute for the Study of Coherence and Emergence, and the Cynefin Centre for Organizational Complexity in accordance with academic publishing standards and processes.

Journal: InterJournal

Publisher:

InterJournal has been developed as part of the activities of the New England Complex Systems Institute. The editors may be contacted for more information. Managing editor: Y. Bar-Yam. System Administration and Development: J. Redi.

Web site(s):

http://interjournal.org/

From the web site:

The InterJournal (ISSN: 1081-0625) differs from conventional paper journals as well as from many electronic journals in a number of ways discussed below. A summary of InterJournal forms follows. Commonly asked questions are also addressed. The InterJournal relies upon authors to store and make their manuscripts available on the Internet. This utilization of the distributed database nature of the WWW enables a number of changes from conventional publication.

- *Redefining the word "manuscript": In recent years one of the major advances in print publication is the introduction of color. The InterJournal takes this further by enabling all possible data formats that can be stored on a computer and transferred through the Internet. A manuscript may consist of: text, color figures and pictures, computr programs, raw data, video, audio and documents that are structured by hyperlinks. While there are many possibilities, authors should use the medium to serve the purpose of communication of results. The opportunity to include raw data and computer programs as part of manuscripts does suggest that publication may be viewed not only as a process of communicating finished results, but also as a more general means of facilitating the advance of science. Providing a common database that contains data and computer programs, rather than just the summary of results possible in print journals, enables new opportunities for what, in effect, become distributed collaborations.*
- *Redefining the function of "refereeing": In recent years electronic databases of preprints have become standard in a number of fields. These databases provide access to manuscripts before they are in print. The InterJournal enables public access to manuscripts immediately upon submission. However, at the discretion of the authors, during an initial refereeing period access may be limited to a few editor selected referees.*

Journal: International Journal of Bifurcation and Chaos (IJBC) in Applied Sciences and Engineering

Publisher:

Editor: L O Chua, Dept. of Electrical Engineering and Computer Sciences University of California at Berkeley, Berkeley, CA 94720, USA.

Web site(s):

http://www.worldscinet.com/ijbc/mkt/editorial.shtml

From the web site:

The International Journal of Bifurcation and Chaos is widely regarded as the leading journal in the exciting field of chaos and nonlinear science. Represented by an international editorial board comprising eighty top researchers from a wide variety of disciplines, it is setting the standard in scientific and production quality. The journal has been highly acclaimed by the scientific community around the world, and has featured many important papers by leading researchers from various fields. The discipline of chaos has created a universal paradigm, a scientific parlance, and a mathematical tool for grappling with nonlinear phenomena. In every field of the applied sciences (astronomy, atmospheric sciences, biology, chemistry, economics, geophysics, life and medical sciences, physics, social sciences, zoology, etc.) and engineering (aerospace, chemical, civil, computer, information, mechanical, software, telecommunication, etc.) the local and global manifestations of Chaos and Bifurcation have burst forth in an unprecedented universality, linking scientists heretofore unfamiliar with one another's fields, and offering an opportunity to reshape our grasp of reality. The primary objective of this journal is to provide a single forum for this multidisciplinary discipline - a forum specifically designed for an interdisciplinary audience, a forum accessible and affordable to all. Real-world problems and applications will be emphasized. Our goal is to bring together, in one periodical, papers of the highest quality and greatest importance on every aspect of nonlinear dynamics, phenomena, modeling, and complexity, thereby providing a focus and catalyst for the timely dissemination and cross-fertilization of new ideas, principles, and techniques across a broad interdisciplinary front. The scope of this journal encompasses experimental, computational, and theoretical aspects of bifurcations, chaos and complexity of biological, economic, engineering, fluid dynamic, neural, physical, social, and other dynamical systems. This broad but focused coverage includes, but is not restricted to, those areas of expertise provided by the members of the editorial board, whose composition will evolve continuously in order to respond to emerging new areas and directions in nonlinear dynamics and complexity.

Journal: International Journal of Chaos Theory and Applications

Publisher:

Editors in Chief: Harold H. Szu, University of Louisiana at Lafayette, Louisiana, USA; Takeshi Yamakawa, Kyushu Institute of Technology, Iizuka, Fukuoka 820, Japan; Horia-Nicolai Teodorescu, Technical University of Iasi, Iasi 6600, Romania *(Managing Editor)*

Web site(s):

http://neurolab.ing.unirc.it/chaos/index.htm

From the web site:

The Journal is intended to promote development of applications and related theory in the field of dynamic systems exhibiting chaotic behavior, in a variety of applied scientific and technical disciplines. The main emphasis is on applications. The Journal aims to advance science and technology of nonlinear processes and systems. For instance, applications of chaos in information processing, memory devices, pattern recognition as a chaotic process, signal processing, prediction, control, virtual reality, composition of music and art works, lasers and nonlinear optics, nonlinear physics, chemical reactivity, growth processes and cooperative processes biology, memory and sense processes as nonlinear dynamic processes, biological pacing systems and their control, and so on, are focused. A special emphasis is on designing methodologies based on chaos generation mechanism, chaos properties, and chaos control. The focus is on systematically developing sound applications based on theoretical advances. A special bulletin section is devoted to carry relevant information on conferences, other events, people, new patents in the field, technical developments (both software and hardware), book reviews, etc.

Journal: International Journal of Complexity (IJC)

Publisher:

INDERSCIENCE Publishers.

Web site(s):

http://www.inderscience.com/browse/index.php?journalID=71

From the web site:

The prime objective of the IJC is to provide a platform to network the various pure and applied science disciplines that underpin the study and design of technological and management systems in industrial companies. The IJC provides a forum to help professionals, academics, researchers and policy makers, working in the field of technology management, operations management, engineering design, technology transfer and organisational design, to disseminate information and to learn from each other's work. The IJC publishes original papers, review papers, technical reports, case studies, book reviews, notes, commentaries, and news. Special Issues devoted to important topics such as supply chain complexity, evolutionary design and the economics of operational complexity will occasionally be published. Commentaries on papers and reports published in the Journal are encouraged. Authors will have the opportunity to respond to the commentary on their work before the entire treatment is published. Contribution may be by submission or invitation, and suggestions for special issues and publications are welcome. The IJC will address two related areas of system design and management:

- *understanding and managing system complexity (complicatedness)*
- *developing and applying complex system methods*

- *Applications areas include:*
- *Supply chains*
- *Scheduling, planning and control*
- *Process and job design*
- *Product design*
- *Innovation processes*
- *Technology transfer*
- *Technology and operations strategy*
- *Sustainability*
- *R&D management*

Journal: International Journal of General Systems

Publisher:

Published By: Taylor & Francis, Thomson ISI Journal Citation Reports.

Web site(s):

http://www.tandf.co.uk/journals/titles/03081079.html

From the web site:

International Journal of General Systems is a crossdisciplinary periodical devoted primarily to the publication of original research contributions to systems science, basic as well as applied. However, relevant tutorial and survey articles, book reviews, bibliographies, and letters to the editor are also published. The principal aim of the journal is to promote original systems ideas (concepts, principles, methods, insightful theoretical or experimental results, etc.) that transcend the boundaries between traditional academic disciplines. The term "general systems" in its name is intended to indicate this aim the orientation to systems ideas that have a general applicability. Some typical subjects covered by the journal include: systems modeling, simulation, and design; systems complexity and simplification methods; crossdisciplinary systems problem solving; and theoretical as well as experimental knowledge regarding various categories of systems, such as hierarchical, cellular, adaptive, self-organizing, learning, autopoietic, self-producing, intelligent, etc.

Journal: International Scientific Journal of Methods and Models of Compelxity

Publisher:

Published on Internet by SISWO, ISSN- 0928-3137.

Web site(s):

http://www.geocities.com/doriendetombe/detombevol7menm2004.html

From the web site:

The Journal deals with the question how complex real life problems can be analyzed and handled with scientific methods and models. Because such problems most of the time cannot be handled by one discipline, the journal is interdisciplinary. Contributions may come from the social and natural sciences that practice interdisciplinary research of complex problems. In the past articles are published with topics as 'Policy making for complex problems', 'Participative Model building in Healthcare', 'Complex System Theory for Analysis of Locomotion', 'Non Linear Models for Economy', 'From Information to Communication', 'Logistic Modeling for Complex Situations', 'Computer Simulation of Chaos and Order', 'Evaluation of Future Predictions'. The publication of the Journal will be one or twice a year. Two referees will review submitted articles, and on their advice the editors will decide about the publication. From time to time a special edition on a theme will be published.

Journal: Journal of Artificial Societies and Social Simulation

Web site(s):

http://jasss.soc.surrey.ac.uk/JASSS.html

From the web site:

Original research papers and critical reviews on all aspects of social simulation and agent societies that fall within the journal's objective to further the exploration and understanding of social processes by means of computer simulation are welcome.

Journal: Journal of Complexity

Publisher:

Elsevier, Customer Service Department, 6277 Sea Harbor Drive, Orlando, FL 32887-4800 USA, Email: usjcs@elsevier.com, Customers Outside US: Tel: +1 (407) 345-4020, Fax: +1 (407) 363-1354.

Web site(s):

http://www.sciencedirect.com/science/journal/0885064X

From the web site:

The multidisciplinary Journal of Complexity publishes original research papers that contain substantial mathematical results on complexity as broadly conceived. Outstanding review papers will also be published. In the area of computational complexity, the focus is on complexity over the reals, with the emphasis on lower bounds and optimal algorithms. The Journal of Complexity also publishes articles that provide major new algorithms or make important progress on upper bounds. Other models of computation, such as the Turing machine model, are also of interest. A

new area is quantum computing. Computational complexity results in a wide variety of areas are solicited. The following is a partial list of topics: applied mathematics, numerical analysis, scientific computation, approximation theory, systems of algebraic equations, differential equations, optimization, control theory, decision theory, design of experiments, distributed computation, information theory, prediction and estimation, and statistics. The Journal of Complexity also addresses such topics as chaos, and complexity in biological, physical, financial, and economic systems.

Journal: Journal of Mathematical Psychology

Publisher:

Elsevier, Customer Service Department, 6277 Sea Harbor Drive, Orlando, FL 32887-4800 USA, Email: usjcs@elsevier.com, Customers Outside US: Tel: +1 (407) 345-4020, Fax: +1 (407) 363-1354.

Web site(s):

http://www.elsevier.com/wps/find/journaldescription.cws_home/622887/description#description

From the web site:

The Journal of Mathematical Psychology includes articles, monographs and reviews, notes and commentaries, and book reviews in all areas of mathematical psychology. Empirical and theoretical contributions are equally welcome. Areas of special interest include, but are not limited to, fundamental measurement and psychological process models, such as those based upon neural network or information processing concepts. A partial listing of substantive areas covered include sensation and perception, psychophysics, learning and memory, problem solving, judgment and decision-making, and motivation. The Journal of Mathematical Psychology is affiliated with the Society for Mathematical Psychology. Research Areas include: Models for sensation and perception, learning, memory and thinking; Fundamental measurement and scaling; Decision making; Neural modeling and networks; Psychophysics and signal detection; Neuropsychological theories; Psycholinguistics; Motivational dynamics; Animal behavior; Psychometric theory.

Journal: Journal of Memetics – Evolutionary Models of Information Transmission

Web site(s):

http://jom-emit.cfpm.org/about.html

From the web site:

The Journal of memetics is a peer-reviewed academic journal. The editors feel that a journal on memetics can be an important place for scientists and professionals to discuss their views and research in memetics. The first issue is scheduled for May 1997. The journal will be published on the Internet without subscription fee. The journal of memetics seeks to develop the memetic

perspective, with space devoted to relevant evolutionary issues and other related topics. We seek to discuss issues concerning memetics such as:

- *Mechanisms involved in evolutionary processes. Comparisons of different models of evolution are especially welcome.*
- *Philosophical or theoretical issues concerning epistemology and evolution*
- *Boundaries of the evolutionary approach*
- *Empirical research*
- *Fundamental approaches aiming at structuring the field of memetics as a science*

Journal: Journal of Military and Strategic Studies

Web site(s):

http://www.jmss.org/

From the web site:

As one of the few electronic journals dedicated to the study of security related issues in Canada, we are pleased to provide a forum in which security issues can be examined and discussed. It is our editorial philosophy that the many issues within the field of military and strategic studies are best understood through an open and frank discussion. Furthermore, it is also our belief that these debates are best served by a mix of academic and policy related approaches. We will therefore remain open to as wide an audience as is possible. We hope that you will find the thoughts expressed in this journal both challenging and stimulating. We invite any responses that you have to these articles or to any other issues pertaining to military and strategic studies by emailing info@jmss.org.

Journal: Journal of Nonlinear Science

Publisher:

Springer. Editor-in-Chief: Jerrold E. Marsden, Journal of Nonlinear Science, Control and Dynamical Systems, California Institute of Technology, CDS 107-81, Pasadena, CA 91127, USA, e-mail: jnlsed@math.princeton.edu

Web site(s):

http://www.springer.com/sgw/cda/frontpage/0,11855,4-40109-70-1100938-0,00.html

From the web site:

The mission of the Journal of Nonlinear Science is to publish papers that augment the fundamental ways we describe, model, and predict nonlinear phenomena. Papers should make an original contribution to at least one technical area and should in addition illuminate issues beyond that area's boundaries. Even excellent papers in a narrow field of interest are not

appropriate for the journal. Papers can be oriented toward theory, experimentation, algorithms, numerical simulations, or applications as long as the work is creative and sound. Excessively theoretical work in which the application to natural phenomena is not apparent (at least through similar techniques) or in which the development of fundamental methodologies is not present is probably not appropriate. In turn, papers oriented toward experimentation, numerical simulations, or applications must not simply report results without an indication of what a theoretical explanation might be.

Journal: Journal of Social Complexity

Publisher:

Bandung FE Institute

Web site(s):

http://josc.bandungfe.net/vol1.html

From the web site:

The Journal of Social Complexity is published in hard copy four times in a year. Here is the list of the journals for the first year the publication. The journal is published in hard-copy and will be available on-line after one year of the publication. Please consider that all papers listed here are copyrighted materials, use the appropriate referential information to cite or quote. The Journal of Social Complexity is the periodic journal that searches the sharp methodology on social system that viewed as complex system. The research papers that published in the journal has to be selected by the BFI Board, has been tested, and qualified for journal publications. The journal is published in hard-copy. However, the first two editions of the journal are also published on-line. Journal of Social Complexity contains five types of contribution: research articles presenting experimental data, computational experiments, mathematical analyses, or clearly-formulated theoretical ideas informal essays presenting more personal, wide-ranging views on aspects of mental process survey articles, presenting summaries of past contributions, or synthesizing ideas and results from different paradigms. brief commentaries, pertaining to the contents of research articles, essays, survey articles, or other commentaries book reviews Authors are invited to submit papers which present innovative, unorthodox interpretations of empirical or computational experiments that have already been described in other publications. Readers are invited to submit commentary items pertaining to the articles in the journal. The ability to present a continuously running stream of commentaries, linked in with articles, is one of the advantages of the electronic format. The level of scholarship involved in commentary items is expected to be well above that of the average Internet newsgroup post. While the scope of Bandung Fe Institute is broad, certain areas are of particular interest to the editors. These include, but are not limited to:

- *Social Simulation & Artificial Societies, the social system analysis while using the agent-based modelling, celullar automata, social network, memetic, dynamical system analysis about anything concerning social conditions.*
- *Cognitive Science, the analysis on dynamical psychology about system of cognitive. This particular areas of interest on this analysis is on consciousness, mental construction of*

reality, or connections between some areas of mind science in the non-linear dynamics and complexity of science discourses.

Journal: Journal of the International Society for Structural and Multidisciplinary Optimization (ISSMO)

Publisher:

Springer

Web site(s):

http://www.springerlink.com/(4pnley55gqy33b45yomkb3rz)/app/home/journal.asp?referrer=parent&backto=linkingpublicationresults,1:102504,1

Journal: Mathematical Models and Methods in Applied Sciences (M3AS)

Publisher:

Wiley Periodicals, Inc., A Wiley Company

Web site(s):

http://emergence.org/

From the web site:

This journal provides a medium of exchange for scientists engaged in applied sciences (physics, biology, economy, finance, social sciences, natural and technological sciences) where there exists a non-trivial interplay between mathematics, mathematical modeling of complex systems and mathematical and computer methods oriented towards the qualitative and quantitative analysis of mathematical models. The principal areas of interest of this journal are: mathematical modeling of systems in applied sciences; mathematical methods for the qualitative and computational analysis of models of systems of real world; and numerical and computational treatment of mathematical models or real systems. Special attention will be paid to the analysis of nonlinearities and stochastic aspects.

Journal: Nonlinear Analysis: Modelling and Control

Publisher:

Lithuanian Association of Nonlinear Analysts

Web site(s):

http://www.lana.lt/journal/

From the web site:

The scope of the journal is to provide a multidisciplinary forum for scientists, researchers and engineers involved in research and design of nonlinear processes and phenomena, including the nonlinear modelling of phenomena of the nature.

Journal: Nonlinear Dynamics, Psychology, and Life Sciences

Publisher:

The Society for Chaos Theory in Psychology & Life Sciences since 1997.

Web site(s):

http://www.societyforchaostheory.org/ndpls/

From the web site:

Nonlinear Dynamics, Psychology, and Life Sciences publishes articles that augment the fundamental ways we understand, describe, model and predict nonlinear phenomena in psychology and the life and social sciences. One or more of the following nonlinear concepts must be an explicit part of the exposition: attractors, bifurcations, chaos, fractals, solitons, catastrophes, self-organizing processes, cellular automata, genetic algorithms and related evolutionary processes, and neural networks. The broad mixture of the disciplines represented here indicates that many bodies of knowledge share common principles. By juxtaposing developments in different fields within the life and social sciences, the scientific communities may obtain fresh perspectives on those common principles and their implications. Because the journal is multidisciplinary in scope, articles should make an original contribution to at least one substantive area and should in addition illuminate issues beyond that area's boundaries. Papers, however excellent that pertain only to an overly narrow field of interest are not appropriate for this journal. Papers must make original contributions to the understanding of dynamical processes as defined above, and the exposition must be rigorous. Papers can focus upon theory, experimentation, algorithms, numerical simulation, applications to problems in any of the foregoing substantive areas, or philosophy of science if the subject matter is explicitly related to research and theory developments nonlinear dynamical systems. Overly abstract papers, however, in which the application to psychology or to life or social science issues is not apparent are not appropriate for this journal. In addition, papers involving experimentation, numerical simulations, or application should include introductory or discussion remarks on the theoretical explanations for the experimental results.

Journal: Nonlinear Phenomena in Complex Systems

Publisher:

"Education and Upbringing" Publishing, Minsk, Belarus

Web site(s):

http://www.j-npcs.org/

From the web site:

The primary objective of Nonlinear Phenomena in Complex Systems (NPCS) is to provide a single forum for this interdisciplinary area to strengthen links between basic and applied research, theoretical and experimental methods relating to nonlinear dynamics of complex systems encountered in the natural and social sciences. Its goal is to bring together, in one periodical, significant papers of high quality on all aspects of nonlinear dynamics, including phenomena, modelling, and complexity, thereby providing a focus and catalyst for the timely dissemination and cross-fertilization of new ideas, principles, and techniques across a broad interdisciplinary front. The scope of this international journal includes experiment, computational, and theoretical aspects of phase transitions, critical phenomena, self-organization, bifurcations, chaos, fluctuation phenomena, pattern formation, fractals and complexity in physics, mathematics, chemistry, engineering, biology, social and economic sciences and the other areas of Scientific endeavour

Journal: Open Systems and Information Dynamics

Publisher:

Springer Netherlands

Web site(s):

http://www.springer.com/sgw/cda/frontpage/0,11855,5-0-70-35600820-0,00.html?referer=www.wkap.nl

From the web site:

The aim of the Journal is to promote interdisciplinary research in mathematics, physics, engineering and life sciences centered around the issues of broadly understood information processing, storage and transmission, in both quantum and classical settings. Our special interest lies in the information-theoretic approach to phenomena dealing with dynamics and thermodynamics, control, communication, filtering, memory and cooperative behaviour, etc., in open complex systems. The following topics are particularly welcome: theory of quantum information, including quantum entanglement and measurement, quantum communication, computing and cryptography; open systems and decoherence; neural networks and genetic models; information/entropy flow in complex dynamical systems; other models of information processing.

Journal: Progress in Complexity, Information, and Design

Board:

William A. Dembski, General Editor, Jed Macosko, Associate Editor, Bruce Gordon, Associate Editor, James Barham, Book Review Editor, John Bracht, Managing Editor, Micah Sparacio, Webmaster.

Web site(s):

http://www.iscid.org/pcid.php

From the web site:

Progress in Complexity, Information, and Design (PCID) is a quarterly, cross-disciplinary, online journal that investigates complex systems apart from external programmatic constraints like materialism, naturalism, or reductionism. PCID focuses especially on the theoretical development, empirical application, and philosophical implications of information- and design-theoretic concepts for complex systems. PCID welcomes survey articles, research articles, technical communications, tutorials, commentaries, book and software reviews, educational overviews, and controversial theories. The aim of PCID is to advance the science of complexity by assessing the degree to which teleology is relevant (or irrelevant) to the origin, development, and operation of complex systems.

Journal: Regular & Chaotic Dynamics

Publisher:

Turpion Ltd. Editor in Chief: V V Kozlov, V A Steklov Mathematical Institute, RAS, Moscow

Web site(s):

http://www.turpion.org/php/homes/pa.phtml?jrnid=rd&page=ej

From the web site:

In this mathematics journal, special attention is given to: Nonlinear Dynamics; Integrability and Nonintegrability of Dynamical Systems; Determined Chaos; Symmetries, Lie Algebras, and Hamiltonian Formalism; Fractal Dynamics; Selforganization Theory and Synergetics; Quantum Chaos; Computer Dynamics; Vortex Theory; and Nonholonomic Mechanics.

Journal: The Computer Journal

Publisher:

Oxford Journals.

Web site(s):

http://comjnl.oxfordjournals.org/content/vol42/issue4/

Journal: The International Journal of Nonlinear Sciences and Numerical Simulation

Publisher:

Freund Publishing House. Editor-in-Chief: Ji-Huan He, P.O. Box 471, College of Science, Donghua, University, 1882 Yan'an Xilu Road, Shanghai 200051, China, Email:jhhe@dhu.edu.cn Fax: 86-21-62378926.

Web site(s):

http://www.ijnsns.com/editor.html

From the web site:

The International Journal of Nonlinear Sciences and Numerical Simulation publishes original papers on all subjects relevant to nonlinear sciences and numerical simulation. The highest priority will be given to those contributions concerned with a discussion of the background of a practical problem, the establishment of an appropriate nonlinear model, the determination of a solution, approximate or exact, analytical or numerical, and a discussion of the relevance of the results when applied to the real-life problem. The following types of manuscript are encouraged: New nonlinear model for a real-life problem with possible exciting applications; New analytical techniques for new nonlinear problems with physical understanding; and Numerical simulation revealing possible hidden pearls in nonlinear sciences.

Journal: UK Nonlinear News

Publisher:

University of Leeds, Leeds ls2 9jt, UK.

Web site(s):

http://www.maths.leeds.ac.uk/Applied/news.dir/

From the web site:

The primary goal of UK Nonlinear News is to allow researchers in the applied and theoretical sides of nonlinear mathematics to keep abreast of the wide variety of nonlinear activities throughout the UK. Broadly speaking we hope that each issue will carry several articles about various groups and activities, as well as shorter pieces of news, reviews, and questions. Although primarily intended as a service to the UK community, this should not be seen as exclusive, and participation from overseas is welcomed.

8 Conferences, Workshops

Conference: ALIFE X

Web site(s):

http://www.alifex.org/

From the Web site:

Artificial life is the interdisciplinary enterprise investigating the fundamental properties of living systems through the simulation and synthesis of life-like processes in artificial media. The Artificial Life X conference marks two decades of the birth of this enterprise, a period marked by vast advances in the life sciences. The conference will showcase the best current work in all areas of research in Artificial Life, while highlighting its achievements and challenges, especially in an age of unparalleled computational power and access to data about various biological processes. Each day of the conference will also spotlight a specific theme: Development and Embodied Cognition (in collaboration with ICDL5), Achievements and Open Problems, Computational Biology, and Complex Systems and Networks. Both oral and poster presentations will be published in a volume by MIT Press. The organizing Committee of Artificial Life X, Luis M. Rocha (Chair), Mark Bedau, Dario Floreano, Robert Goldstone, Alessandro Vespignani, and Larry Yaeger.

Conference: ANZSYS Conference

Web site(s):

http://isce.edu/ISCE_Group_Site/web-content/ISCE%20Events/Christchurch_2005.html

http://www.monash.edu.au/cmo/anzsys2003/

http://www.hpsig.com/index.php?title=ANZSYS

Conference: Autonomous Computing Workshop

Organization:

Program Chair: Manish Parashar (parashar@caip.rutgers.edu), 504 CoRE, Department of Electrical & Computer Engineering, Rutgers, The State University of New Jersey, 94 Brett Road, Piscataway, NJ 08854-8058, Phone: (732) 445-5388

Web site(s):

http://www.caip.rutgers.edu/ams2003/

From the Web site:

The increasing complexity of networks, services and applications has necessitated investigating the design, development and deployment of active systems, services and applications that are capable of autonomic existence that is they are self-defining, self-configuring, self-optimizing, self-protecting, self-healing, context aware and anticipatory. The 5th Annual International Active Middleware Services Workshop will focus on the Autonomic Computing and will bring together leading researchers and ideas in this emerging discipline.

Conference: Colloquium on Structural Information and Communication Complexity

Web site(s):

http://sirocco06.csc.liv.ac.uk/

Conference: Complex Adaptive Systems Symposium

Web site(s):

http://www.dsto.defence.gov.au/events/4197/

From the Web site:

The field of Complex Adaptive Systems combines both complexity – present in highly correlated systems which display interesting behaviour but don't obey simple cause-effect relationships, and adaptivity – a very desirable property which is manifested as intelligent context-appropriate autonomous behaviour even in hostile environments. The theme of the CAS Symposium is Understanding Adaptivity to Deal with Complexity, and it aims to:

- *Acquaint TTCP and national Defence communities with important conceptual advances in CAS science, and in its application to defence problems arising from complexity - both in our own systems and in the context in which defence operates;*
- *Present the state-of-the-art in CAS research and thinking in the context of defence challenges, and the exciting potential of this approach in dealing with complexity related issues;*
- *Place particular emphasis on the conceptual tools needed to leverage the power of adaptivity to increase the effectiveness of our own complex systems and to influence the behaviour of other self-modifying learning systems; and*
- *Engage wider TTCP participation in the needed research agenda to further develop what is still a relatively immature, but very rapidly developing and promising field of defence science.*

Conference: Complexity in Design and Engineering

Web site(s):

http://www.dcs.gla.ac.uk/~johnson/complexity/

http://www.iproms.org/node/157

From the Web site:

On 10th March we will focus on the Design of Complex Systems. The intention is to explore the many different challenges that are facing designers in a range of application domains. For example, mechanical engineers must develop products that go faster, require less maintenance, use less raw materials than ever before. These demands are compounded by the increasing emphasis on mathematical modelling and simulation rather than destructive testing. Similarly, software engineers are being asked to develop systems that interact with these devices and with human operators. Increasingly the demands of developing safety-critical systems are being exacerbated by the need to produce `band-aid' software that addresses known problems in the underlying mechanical and materials engineering or that addresses underlying human factors problems in the usability of an application. On the 11th March, we will focus on the Complexity of Design. The intention is to explore the many different challenges that complicate innovative design. These challenges do not simply come from the types of novel applications that will be discussed on the first day. They also stem directly from the application of particular development techniques. For instance, re-use simplifies many aspects of complex systems design. These techniques also carry important overheads; it can be hard to ensure that an implementation satisfies the intended requirements within its new context of use. This applies to software engineering just as it does to mechanical engineering. These comments may also, arguably, be applied to the reuse of design processes and teams. Similarly, risk assessment has been used to guide the development of many previous generations of complex systems. However, the increasing integration of large scale application processes and the inter-disciplinary nature of many engineering endeavours makes it hard to sustain this approach from individual component reliability up to the `systems' level. We encourage papers from a wide range of application domains including but not limited to finance, healthcare, aerospace and the military.

<u>Conference</u>: Complexity, Science and Society Conference

Web site(s):

http://www.liv.ac.uk/ccr/2005_conf/subject_areas/elec_eng.htm

From the Web site:

Complex systems are characteristically composed of many independent agents interacting with each other in many ways, capable of self-organization and actively adapting (Mitchell Waldrop, 1992). Broadly, they involve societies and networks of communicating entities. In electrical engineering and electronics (EEE), complexity is increasing in a number of inter-related ways – the technology and infrastructures, the system design and architectural processes, and the areas of application in society that they support. In the case of design, the objective in EEE, generally, is to realise predictable and consistent system behaviour through processes of design, engineering and system assurance. These creative processes are themselves becoming increasingly complex combinatorial and computational activities, as developments in fields such as integrated circuit packing density, system on chip integration, Application Specific Integrated Circuits, reconfigurable hardware (e.g. Field Programmable Gate Arrays), and nanotechnology, are expanding the frontiers of EEE into areas that can support ever higher system complexity. Moore's Law on the doubling of processing power every 6 months (http://www.intel.com/technology/silicon/mooreslaw/index.htm) is holding in silicon and may

transfer to another medium. EEE's basic entities are switches but the developments in miniaturisation, increasing speed, and reduced energy consumption – together achieving more with less – mean that the technology can increasingly support emergent complex adaptive entities that can sense, have memory, learn, act, predict and take risks - agents. Already, tools and techniques such as adaptive filters, sensor fusion, maximum likelihood algorithms, and least known complexity are being applied in data transmission and storage, coding/decoding, communication and signal processing, and hybrid systems. The technology developments present enormous possibilities and challenges. For example, software could run on reconfigurable hardware at enormous speeds to evolve advanced circuits (e.g. Koza) and solutions to complex problems, leading to the possibility ultimately of artificial brains. With developments in mechatronics, these could be installed in robots. Alongside the potential opportunities, one of the major issues in this area is the management of complexity. Thirdly, complex systems are being deployed to support complex social needs in areas such as medicine, care and welfare, and security. There is great scope here as well for synergies between complexity, science and society. This conference session aims to explore these ideas from the three perspectives of complexity in EEE technology, system design, and social systems. Because these threads involve multiple theoretical and applied disciplines, the session hopes to generate multi-disciplinary conversations, debate and exchange, and explore synergies.

- *Topics of possible interest include (but are not limited to):*
- *Designing complex, adaptive EEE systems*
- *Complex, adaptive EEE systems in society*
- *Technology developments and their potential*
- *Tools and techniques used to harness complexity*
- *Management and control of complex, adaptive systems*

Conference: Computability & Complexity in Analysis

Web site(s):

http://cca-net.de/

From the Web site:

Computability theory and complexity theory are two central areas of research in mathematical logic and theoretical computer science. Computability theory is the study of the limitations and abilities of computers in principle. Computational complexity theory provides a framework for understanding the cost of solving computational problems, as measured by the requirement for resources such as time and space. The classical approach in these areas is to consider algorithms as operating on finite strings of symbols from a finite alphabet. Such strings may represent various discrete objects such as integers or algebraic expressions, but cannot represent a general real or complex number, unless it is rounded.The classical theory of computation does not deal adequately with computations that operate on real-valued data. Most computational problems in the physical sciences and engineering are of this type, such as the complexity of network flow problems and of dynamical and hybrid systems. To study these types of problem, alternative models over real-valued data and other continuous structures have been developed in recent

years. Unlike the well established classical theory of computation over discrete structures, the theory of computation over continuous data is still in its infancy. Scientists working in the area of computation on real-valued data come from different fields, such as theoretical computer science, domain theory, logic, constructive mathematics, computer arithmetic, numerical mathematics, analysis, etc. The aim of CCA Network is to provide some useful information for researchers working in the field of computability and complexity in analysis. In particular, we offer:

- *a list of members, including references to homepages and email addresses,*
- *a mailing list,*
- *a bibliography,*
- *links to related conferences and workshops,*
- *links to related publications.*

Conference: Electronic Colloquium on Computational Complexity

Web site(s):

http://eccc.hpi-web.de/eccc/

Conference: Engineering Emergence for Autonomic Systems

Web site(s):

http://cms1.gre.ac.uk/Research/SOACS/ICAC-ws/subsite/

From the Web site:

Emergence is a phenomenon that is intrinsically associated with autonomic systems, arising because of the interactions between the various components. However, some systems go beyond this incidental occurrence of emergence; actively employing the emergent behaviour in constructive ways. This workshop is of great significance to ICAC delegates because it is concerned with the important link between autonomics and emergence, and will provide a lively forum for discussion of the nature of the relationship and provide a platform for the presentation of research into the purposeful exploitation of emergence. The workshop intends to discuss applications of emergence in autonomic computing, and the associated issues. These include inter alia: interaction mechanisms; composition; contextual awareness; stability and behavioural scope in real-world contexts; and verification techniques.

Conference: Engineering Systems Symposium – MIT Engineering Systems Division

Web site(s):

http://esd.mit.edu/symposium/agenda_day3.htm

Conference: Engineering with Complexity and Emergence (ECE'05)

Web site(s):

http://www.davidhales.com/ece2005

From the Web site:

New software engineering paradigms are being created by harnessing the properties of complex systems such as emergence. This radical new approach to building robust, scalable and practical systems is influenced, but not limited to, inspiration from both biological systems and social systems. These systems demonstrate some very "nice" properties that engineers strive for. For example, properties of self-repair, self-management and self-adaptation to changing environments. These so-called "self-star" (or self-) properties are increasingly sought by engineers working with complex "always-on" distributed information systems. This is because central control, administration and programming of massively distributed semi-autonomous entities is not a realistic option. But currently the engineering of such systems is a "black art" with little established methodology or toolbox of dependable and tested mechanisms that can harness emergence for self-organisation and management tasks. Some even claim that "emergence", by definition, can never be used for engineering since it depends on surprise or unexpected behaviour. In this workshop we aim to address and discuss these issues by bringing together leaders in the field and showcasing the best recent work that harnesses complexity and emergence to solve hard engineering problems within information systems. We will include presentations from the concluding EU BISON project and the on-going EU DELIS project.*

Conference: European Conference on Complex Systems (ECC)

Web site(s):

http://complexsystems.lri.fr/Portal/tiki-index.php?page=ECCS%2706

http://www.sbs.ox.ac.uk/events/European+Conference+on+Complex+Systems+2006.htm

http://www.accs.uq.edu.au/index/news-app/story.97/title.european-conference-on-complex-systems-2006/menu.no/sec./home.

From the Web site:

Complex systems, as networks of interacting entities, are studied empirically through the rapidly increasing mass of data which has become available in many different domains. At the same time, these different domains also appear to share many new and fundamental theoretical questions. These circumstances should encourage the interdisciplinary development of a new science of complex systems. It is possible to identify two kinds of interdisciplinarity within complex systems research. The first begins with a particular complex system and addresses a variety of questions coming from that particular domain and disciplinary point of view. This may lead to the emergence of new domain-specific interdisciplinary fields such as cognitive science. The second kind of interdisciplinarity starts from questions that are fundamental to complex systems in general. The new science of complex systems is primarily characterised by this second kind of interdisciplinarity, which starts from fundamental open questions relevant to many domains, and searches for general methods to deal with them. These two kinds of interdisciplinarity are

complementary and interdependent: any advance in one can lead to progress in the other. The new science of complex systems will need to develop through a continually renewed process of reconstructing data from models, and will require engagement with both kinds of interdisciplinarity. In particular, modelling and understanding the dynamics of complex systems remains one of the major challenges for modern science. Our increasing ability to address this challenge is based on a combination of the growing mass of empirical data which has recently become accessible, and the large increase in computational power which can support and underpin significant advances in our theoretical understanding of complex systems.

ECCS '06 is the second in an annual series of conferences organised by the new European Complex Systems Society. The European Commission is providing financial support for the conference through the ONCE-CS and GIACS Coordination Actions, which are funded under the Sixth Framework by the Future and Emerging Technologies Unit of the Information Society Technology (IST) Programme and the New and Emerging Technology (NEST) initiative respectively. Additional financial support for student bursaries and satellite workshops has been made available by the UK's Engineering and Physical Sciences Research Council (EPSRC). The current conference follows ECCS '05, the first conference organised by the European Complex Systems Society, which was held in Paris on 14-18 November 2005. An earlier European Conference on Complex Systems was held in Turin on 5-7 December 2004.

Conference: IEEE Symposium on Logic in Computer Science

Web site(s):

http://www2.informatik.hu-berlin.de/lics/

Conference: IEEE/WIC/ACM International Joint Conference on Web Intelligence and Intelligent Agent Technology

Web site(s):

http://www.hds.utc.fr/WI05/

Conference: International Council on Systems Engineering

Web site(s):

http://www.incose.org/ProductsPubs/symposia/symposiahistory.aspx

Conference: International Workshop on Complexity and Philosophy

Web site(s):

http://isce.edu/ISCE_Group_Site/web-content/ISCE%20Events/Stellenbosch_2007.html

From the Web site:

One of the primary reasons for the existence of the ISCE Group is to encourage and facilitate cross-disciplinary communication and collaboration between different fields of academia and practitioners attempting to apply complexity-inspired concepts and frameworks in the field. This aim is achieved through our own inhouse research programmes and our publishing activities, but primarily through the organization of events. ISCE Events organizes three different sorts of events each with its own particular mode of operation:

- *Workshops: these events are normally restricted to around 30 participants to encourage as much critical discussion as possible. The focus is not on individual presentations, but on different topics that provide the focus of interactive discussion periods. Usually a topic is briefly introduced by a presenter, whose paper would have been made available in advance of the event. This is then followed by a 1.5-2 hour period of discussion in which that particular topic/theme is explored. The aim of workshops is not so much the dissemination of knowledge but the examination of knowledge through intimate and critical reflection.*
- *Conferences: these are the usual bread and butter of an academic institution. The purpose is to present one's work and to listen to others' work on a particular topic. A secondary, but by no means unimportant, aspect of these events is networking. There is no size limit with such events with the focus being on knowledge dissemination and networking. More often than not some kind of proceedings (i.e. a collection of papers) is produced as a record of the event.*
- *Seminars: these events are quite different from the both workshops and conferences, in that their aim is to educate those unfamiliar with complexity thinking and to offer practical advice and analysis of real world problems to faciliate the move from academia to practice.*

ISCE Events organizes all these different types of event, often in collaboration with one or more other institutions. If your institution is keen on co-hosting a complexity-related events with ISCE Events then please let us know and we'd be more than happy to offer any support we can. If you'd like to kept up-to-date with our upcoming events, books and journal issues then please send an email to subscribe@isce.edu.

Conference: Self-Organization and Adaptation of Multi-agent and Grid Systems (SOAS 2005)

Web site(s):

http://lists.w3.org/Archives/Public/www-rdf-logic/2005Aug/0001.html

From the Web site:

A multi-agent system is such a system that is comprised of a collection of fully or semi-autonomous entities/components and whose global behaviours come from the emergent interactions among these entities/components. Such multi-agent systems have been studied widely, not only in computer science, software engineering and artificial intelligence, but even more widely in economics, management science, sociology, systems science, etc. In fact, multi-agent systems permeate social, economic, and technical domains. Grid computing is the new generation distributed and networked information and computing systems which have the capacity to enable users and applications in an emergent manner to transcend the organizational

boundaries and to gain access to the local computing resources administrated by different organizations. A Grid computing system is by nature a large, complex, and open multi-agent system. Grid computing integrates distributed computing resource management, semantic web technology, service oriented architecture and service management, distributed workflow management, monitoring and control of distributed problem solving, etc. While self-organization and adaptation have been studied intensively in control theory, systems theory, adaptive complex systems, robotics, etc., they are relatively new concepts for computing systems. In recent years it has widely been recognized that large complex computing systems are increasingly demanding self-organization and adaptation, as advocated by the autonomic/adaptive computing initiatives in, e.g., IBM, HP, etc. The challenge here is that computing systems basically are artificial systems, which prevents conventional principles and approaches for self-organization and adaptation, which are mainly aimed at physical laws governed systems, from being applied to computing systems. To tackle the complexities of physical laws governed systems such as openness, uncertainty, discrete event randomness, etc., there have been established frameworks of principles and approaches for understanding and engineering self-organization and adaptation. However, for artificial systems such as large complex computing systems, the understanding of the openness, uncertainty, discrete event dynamics, etc. is still very limited and the framework for self-organization and adaptation has yet to be established. To respond to the challenge above, apparently there is the urgency to have a focal forum to exchange and disseminate the state-of-the art developments from different disciplines. The SOAS'05 Conference aims to provide a timely forum to present the latest theoretical and practical results on self-organization and adaptation that have been arising in recent years in the areas of Multi-agent Systems, Grid Computing and Autonomic/Adaptive Computing. SOAS'05 Conference will also serve as an exclusive opportunity to think about the challenges and to shape the future. SOAS'05 Conference is an integral event and is comprised of six thematic Workshops as follows.

- *Workshop 1: Self-Organization, Adaptation, and Learning of Multi-Agent Systems*
- *Workshop 2: Self-Organizing Grid Computing and Adaptive Grid Service Management*
- *Workshop 3: Autonomic and Adaptive Computing*
- *Workshop 4: Basic Principles and Methodologies of Self-Organization and Adaptation*
- *Workshop 5: Prototypes, Case Studies and Applications*
- *Workshop 6: Works in Progress and Doctoral Research*

Conference: Systems Engineering Society of Australia (SESA) (Workshop on Complexity in Information and Communications Technology [ICT] Systems)

Web site(s):

http://www.sesa.org.au/

Conference: System of Systems Engineering Conference

Organization:

System of Systems Engineering Center of Excellence

100 CTC Drive, Johnstown, PA 15904, 1-800-518-0493

Web site(s):

http://www.sosece.org/

From the Web site:

This conference seeks to create an interactive forum for Scientists, Systems Engineers, Engineers, Acquisition Professionals, Program Executive Officers, Program Managers, Managers, Analysis Professionals, Joint Staff, and Policy Makers from government, academia, and industry to discuss the implication of Systems of Systems (SoS) in today's environment. Participants will discuss and exchange ideas and perspectives on the following topics: Perspectives on System of Systems (SoS) approaches, methods, processes, and practices; Application examples of developing, managing, and operating a System of Systems (SoS); Success stories and critical considerations based on experiences; System of Systems (SoS) measurement and analysis, measures of performance.

Conference: Swarm-Robotics.org

Organization:

William M. Spears, Associate Professor of Computer Science, Director, UW Distributed Robotics Laboratory, with Diana Spears. Computer Science Department (ENG 4071A), Dept 3315, 1000 E. University Avenue, Laramie, WY 82071, Phone: 307.766.5429

Web site(s):

http://swarm-robotics.org/

From the Web site:

Swarm robotics is the study of how large number of relatively simple physically embodied agents can be designed such that a desired collective behavior emerges from the local interactions among agents and between the agents and the environment. It is a novel approach to the coordination of large numbers of robots. It is inspired from the observation of social insects ---ants, termites, wasps and bees--- which stand as fascinating examples of how a large number of simple individuals can interact to create collectively intelligent systems. Social insects are known to coordinate their actions to accomplish tasks that are beyond the capabilities of a single individual: termites build large and complex mounds, army ants organize impressive foraging raids, ants can collectively carry large preys. Such coordination capabilities are still beyond the reach of current multi-robot systems.

Conference: The 4th International Workshop on Engineering Self-Organizing Applications (ESOA'06)

Web site(s):

http://esoa.altarum.net/esoa06/

From the Web site:

Today's information infrastructure is a global complex system that consists of great numbers of local interacting components, a system that is so complicated and dynamic that centralized hierarchical control is generally not an option. To be able to competently operate in and fruitfully contribute to this infrastructure, one must engineer systems that are able to adapt to the constant environmental uncertainty and the failure or replacement of its components, without direct human intervention. An attractive approach to meeting this challenge is to utilize the principle of self-organizing local-to-global emergence. This approach is based on the idea that rich and complex global properties can emerge from purely local interaction between agents. Such systems generate order via self-organization, self-regulation, self-repair and self-maintenance and no global or central organizer is required. However, when designing a system that is based only on local interactions and the emergent properties resulting from these interactions, it is a difficult research problem to characterize the global behavior of the system as a whole. Self organizing applications (SOAs) should be based on such an analysis and understanding. More specifically: how do we structure the application components and their interactions, so that the self-organization process results in the desired functionality? How do we validate that the application performs to the requirements within the range of scenarios expected during deployment? What means of influencing the dynamics of the application are available, and how effective are they? To address these questions, approaches originating from diverse areas such as non-linear optimization, knowledge-based programming and constraint problem solving are currently being explored. Multi-agent simulations and analytic modeling can be used to study emergent behavior in real systems. On the other hand, results issued from complexity theory can be applied in engineering of both multi-agent systems and self-organizing systems. Furthermore, SOA engineers often take inspiration from biology, chemistry, sociology and the physical world. For example, typical examples of SOAs are systems that reproduce socially-based insect behavior, such as ants-based systems, artificial life, or robots. The goal of this workshop is to advance the state of the art, investigating the problems mentioned above, and putting a particular emphasis on an interdisciplinary approach. We encourage the communication and cross-fertilization of several fields including: agent-based systems, software engineering, information systems, distributed systems, complex systems, optimization theory and non-linear systems, neural networks, and evolutionary computation. The ESOA'06 workshop welcomes papers on any specific aspect that may support an engineering approach to self-organizing applications, including:

- *Foundational papers addressing formal definitions, modeling, specification and analysis of self-organizing and emergent behavior*
- *Methodological papers related to the engineering, monitoring and control of software with emergent behavior*
- *Middleware infrastructure papers presenting the characteristics and features of software infrastructures to support execution of adaptive components*
- *Industrial applications of self-organizing / emergent software*
- *Interpretation and discovery of examples of self-organized "engineering" in natural systems.*

Conference: The 6th Understanding Complex Systems Symposium

Web site(s):

http://www.how-why.com/ucs2006/index.html

From the Web site:

The symposium Understanding Complex Systems is designed to bring together researchers from many academic disciplines and industry and stimulate cross-disciplinary research activities to build and advance the Complex Systems Research community. A small group of distinguished invited speakers will introduce key complex systems concepts in the context of their discipline. These invited plenary talks are on a 'Scientific American' level. Three hands-on tutorials are in parallel with technical sessions, covering the most recent research findings. The organizers will provide information about funding opportunities for complex systems research and promote linkages for interdisciplinary proposals. One session will be on defense issues, ranging from agent simulations of insurgencies to landmine counter-measures.

Conference: The 8th IEEE International Conference on Engineering of Complex Computer Systems

Web site(s):

http://ise.gmu.edu/iceccs2002/

From the Web site:

Complex computer systems are common in many sectors, such as manufacturing, communications, defense, transportation, aerospace, hazardous environments, energy, e-commerce, and health care. These systems are frequently distributed over heterogeneous networks, and are driven by many diverse requirements on performance, real-time behavior, fault tolerance, security, dependability, adaptability, development time and cost, long life concerns, and other areas. In addition, the emerging area of web-based software requires solutions to complex problems of highly integrated and complex components. Such requirements frequently conflict, and their satisfaction therefore requires managing the trade-off among them during system development and throughout the entire system life. The goal of this conference is to bring together industrial, academic, and government experts from a variety of user domains and software disciplines, to discuss how the different disciplines' problems and solution techniques interact within the entire system. Researchers, practitioners, tool developers and users, and technology transition experts are all welcome. The scope of interest includes long-term research issues, near-term complex system requirements and promising tools, existing complex systems, and commercially available tools.

Conference: The 8th International Workshop on Approximation Algorithms for Combinatorial Optimization Problems and 9th International Workshop on Randomization and Computation

Web site(s):

http://cui.unige.ch/tcs/random-approx/2005/

<u>Conference</u>: The 9th IEEE International Conference on Engineering of Complex Computer Systems

Web site(s):

http://www.dsi.unifi.it/iceccs04/

From the Web site:

As society increasingly depends on software, the size and complexity of software systems continues to grow making them more difficult to understand and evolve. Manifold dependencies between critical elements of software now drive software architectures and increasingly influence the system architecture Complexity of software systems has grown significantly, pervading several key application areas including Manufacturing, Communications, Transportation, Internet, Mobile, Healthcare, Aerospace, and Energy. These systems are frequently distributed over heterogeneous networks, recently involving Internet and Intranet technologies. Inundated by temporal constraints, boundless functionalities, complex algorithms, distributed and mobile architectures, security constraints, reliability, high performance, interoperability, and the like, these complexities are further weighing down development and evolution of today's software systems and ultimately the organizations they serve. To cope with complexity, software systems are modeled or specified using multi-paradigm approaches and require instruments and tools to visualize and understand. Whether traditional, formal models or more innovative approaches are employed; these solutions are at the frontier of the software engineering. The goal of this conference is to bring together industrial, academic and government experts, from a variety of user domain and software disciplines, to examine key complexity problems and effective solution techniques. Researchers, practitioners, tool developers and users, and technology transition experts are all welcome. The scope of the interest includes long-term research, near-term complex system requirements and promising tools, existing systems, and commercially available tools.

<u>Conference</u>: The 11th IEEE International Conference on Engineering of Complex Computer Systems

Web site(s):

http://www.iceccs.org/

From the Web site:

With the ever expanding range of computing platforms and applications, system complexity is on the rise. Increasing intelligence and autonomics in today's systems requires innovative approaches to address these concomitant complexity issues. At this cross-section of volume and complexity, current technologies are often ineffective at coping with the demands for quality computer systems. Manifold dependencies between the critical software, hardware, communications, and human elements now drive computer system and software architectures. Complexity of software systems has grown significantly, pervading several key application areas including Manufacturing, Communications, Transportation, Internet, Entertainment, Mobile, Healthcare, Aerospace, and Energy. These systems are frequently distributed over heterogeneous

networks, involving Internet technologies. Inundated by temporal constraints, boundless functionalities, complex algorithms, distributed and mobile architectures, security constraints, reliability, high performance, interoperability, security, and the like, these complexities are further weighing down development and evolution of today's software systems and ultimately the organizations they serve. To cope with these and other complexity issues, computer systems are modeled or specified using multi-paradigm approaches often requiring instruments and tools to visualize and understand. Advancements in formal modeling, instrumentation, and information visualization are providing traction on this important area. Whether traditional, formal models or more innovative approaches are employed; these solutions are at the frontier of systems and software engineering. The goal of this conference is to assemble industrial, academic and government experts, from a variety of user domains and software disciplines, to examine key complexity problems and effective solutions. Researchers, practitioners, tool developers and users, and technology transition experts are all welcome. The scope of the interest includes long-term research, near-term complex system requirements and promising tools, existing systems, and commercially available tools.

Conference: The 13th Annual European Symposium on Algorithms

Web site(s):

http://www.lsi.upc.edu/~algo05/?cmd=esa2005

Conference: The 15th International Symposium on Fundamentals of Computation Theory

Web site(s):

http://www.tcs.uni-luebeck.de/fct2005/

Conference: The 21st Annual IEEE Conference in Computational Complexity

Web site(s):

http://facweb.cs.depaul.edu/jrogers/complexity/cfp.htm

Conference: The 23rd International Symposium on Theoretical Aspects of Computer Science

Web site(s):

http://www.lif.univ-mrs.fr/STACS06/index.php

Conference: The 27th International Conference on Application and Theory of Petri Nets and Other Models Of Councurrency

Web site(s):

http://www.cs.abo.fi/atpn2006/

Conference: The 33rd International Colloquium on Automata, Languages and Programming

Web site(s):

http://icalp06.dsi.unive.it/

9 Tools for Complexity Science

<u>Scientific document</u>: Methods and Techniques of Complex Systems Sciences: An Overview (Shalizi, 2006)

Author(s):

Cosma Rohilla Shalizi (cshalizi@umich.edu)

Center for the Study of Complex Systems, University of Michigan.

From the document:

In this chapter, I review the main methods and techniques of complex systems science. As a first step, I distinguish among the broad patterns which recur across complex systems, the topics complex systems science commonly studies, the tools employed, and the foundational science of complex systems. The focus of this chapter is overwhelmingly on the third heading, that of tools. These in turn divide, roughly, into tools for analyzing data, tools for constructing and evaluating models, and tools for measuring complexity. I discuss the principles of statistical learning and model selection; time series analysis; cellular automata; agent-based models; the evaluation of complex-systems models; information theory; and ways of measuring complexity. Throughout, I give only rough outlines of techniques, so that readers, confronted with new problems, will have a sense of which ones might be suitable, and which ones definitely are not.

9.1 Frameworks

<u>Framework</u>: Department of Defence Architecture Framework (DODAF)

Author(s):

US Department of Defence

From http://www.software.org/pub/architecture/dodaf.asp:

Background

In response to increasing needs for joint and multinational military operations, the DoD has become increasingly aware of the need for a standard architectural approach to ensure that its systems can communicate and interoperate. Beginning in 1995, the DoD has developed guidance on architecture development. The C4ISR Architecture Framework, Version 1.0 was published in 1996. Version 2 of the framework was published in 1997. After experience with these versions and in recognition of the need to strengthen adoption, the DoD began work on a new version. On August 30, 2003 the DoD Architecture Framework (DoDAF), Version 1.0 was release.

Intent

The DoDAF is intended to ensure that the architecture descriptions developed by the Commands, Services, and Agencies are interrelatable between and among each organization's operational, systems, and technical architecture views and are comparable and integrable across Joint and combined organizational boundaries.

Scope

The framework provides rules and guidance for developing and presenting architecture descriptions. The products defined by the framework are the work products of architecture development, the descriptive artifacts that communicate the architecture.

The framework provides direction on how to describe architectures; it does not provide guidance in how to construct or implement a specific architecture or how to develop and acquire systems or systems-of-systems. This framework covers the military domain and is used mainly by the DoD.

Principles

Complete architectural descriptions require the use of multiple views, each of which conveys different aspects of the architecture in several products (descriptive artifacts or models). The DoDAF defines the following views:

Operational View depicts what is going on in the real world that is to be supported or enabled by systems represented in the architecture. Activities performed as parts of DoD missions and the associated information exchanges among personnel or organizations are the primary items modeled in operational views. The operational view reveals requirements for capabilities and interoperability.

Systems View describes existing and future systems and physical interconnections that support the DoD needs documented in the operational view.

Technical Standards View catalogs standard (COTS, GOTS) system parts or components and their interconnections. This view augments the systems view with technical detail and forecasts of standard technology evolution.

All View augments the other views by providing context, summary or overview-level information, and an integrated dictionary to define terms.

Structure

The DoDAF contains four main types of guidance for architecture development:

Guidelines, which include a set of guiding principles and guidance for building architectures that are compliant with the framework

High-level process for using the framework to develop architecture descriptions that fulfill a purpose

Discussion of architecture data and tools that can serve as facilitators of the architecture-description process

Detailed description of the products

Guidance

The DoDAF is organized into three volumes. Volume I provides general guidance on the need for and use of architecture descriptions in the DoD context. Volume II provides detailed definitions of the 26 products contained in the 3 views. The third volume is a deskbook that provides examples of compliant architectures, approaches to architecture development, and information on reference resources.

Data and Tools

The CADM is a formal model of architecture products, structures, and their interrelationships. The CADM is aimed at providing a common schema for repositories of architecture information. Tool builders or vendors providing support for DoDAF-style architecture descriptions would implement the CADM with a database.

A repository based on the CADM would be able to store architecture products from multiple, framework-based architecture projects in a common way, so that products from different projects, organizations, or Services could be analyzed and compared.

The DARS, under concurrent development with the DoDAF, is a repository for approved architecture information.

Products

The DoDAF defines 26 different architecture products, which are organized into the All, Operational, Systems, and Technical Standards views. The DoDAF emphasizes the need for developing or presenting the products that are appropriate for a given audience. With a CADM-based tool set or repository, extracting and presenting an appropriate subset of the architectural information should be automated at least partially.

A comprehensive description of the products is provided in Volume II.

Compliance

In order to comply with the framework, architecture descriptions must:

- *Include the appropriate set of products for the intended use*
- *Use the common terms and definitions as specified in the framework*
- *Be consistent with the GIG Architecture and the JTA*
- *Describe interoperability requirements in a standard way*

Sources

DoD Architecture Framework, version 1.0

Case Study

DODAF Case Study - *This case study's objective is to increase understanding of the DoDAF by walking through an example.*

Framework: Levels of Information Systems Interoperability (LISI) (LISI, 1998)

Author(s):

MODAF Partners

Web site(s):

http://www.modaf.com/

From the web site:

- ***Levels of Information Systems Interoperability (LISI)****: LISI (Levels of Information Systems Interoperability) is a set of models and associated processes developed by the DoD C4ISR Working Group for assessing information systems' capabilities and implementation in context with the degree of interoperability required.*
- ***State of the Practice****: LISI is perhaps the most widely recognized model of interoperability. Even though it was developed in 1998, LISI continues to be referenced today. LISI combines a basic reference model with mechanisms for developing an Interoperability Profile for an individual system, and for comparing the profiles of individual systems in order to predict the potential for interoperability among systems.*
- ***Impact for Systems of Systems****: While LISI itself has not been universally accepted, several current DoD programs are attempting to accomplish what LISI tried to do: provide a mechanism for measuring the interoperability of a system. If anything, the need for such a mechanism has increased within the DoD due to an emphasis on transforming the existing and future force into a highly networked, information dependent, interoperating capability. New models of interoperability are being defined that purport to measure interoperability in order to support the POM cycle allocation of funds.*
- ***Methods and Approaches****: LISI models depict five levels of interoperability maturity, attributes associated with the levels, and a matrix of the five levels and attributes. LISI categorizes the aspects of interoperability into four interrelated attributes: Procedures, which reflects the doctrine, policies and procedures, architecture, and technical standards that enable systems to exchange information; Data, which reflects formats and protocols that enable data interchange, along with the shared semantics that enable information interchange; Applications, which reflects the applications that enable exchange, processing, and manipulation; Infrastructure, which reflects the environment (hardware, networks, systems services, etc.) that enable interaction. Collectively these attributes are refer as PAID: The matrix created by crossing the five interoperability levels with the four PAID attributes results in the LISI reference model. The LISI reference model provides the basis for a mechanism for discussing interoperability between systems. The LISI Capabilities*

Model extends the LISI Reference Model by providing detail necessary for establishing interoperability metric and for comparing systems. Detail provided includes the implementation options (listed in a supporting Implementations Options Tables) that a developer can make in achieving a specific capability. For example, the World-wide Network capability could be achieved via SIPRNET, NIPRNET, JWICS, or certain other network capabilities. An Interoperability Profile for a system is built by overlaying information about system implementation choices on the LISI Capabilities Model. Using defined processes that rely on Interoperability Profiles, LISI provides mechanisms for comparing potential interoperability between sets of systems.

- ***Open Issues**: The LISI approach is intriguing because it provides a fairly detailed model of interoperability as well as a mapping between the model and implementation technologies, and because it purports to measure interoperability. We sympathize with the need to categorize systems and indicate whether they can interoperate, but we have two major concerns with the approach. First, LISI reflects the sets of standards and interoperability expectations in force within the DoD at the time of its creation. LISI authors recognized the risk of becoming "stale" and stated that the Interoperability Options Tables should be updated to reflect new technology and approaches. Nevertheless, the LISI Reference Model itself contains certain technological assumptions (e.g., Interactive represents an enhanced capability over groupware) that reflect a specific technology bias. Second, and far more significant, we believe that two systems with a high shared interoperability profile (high specific level of interoperability in LISI vernacular) will not necessarily be highly interoperable. This occurs because differences in qualities of service, the intended use of the systems, the way data is used, or in many other factors, may render two systems non-interoperable, even when the technical underpinnings of the systems are identical.*

<u>Framework</u>: MODULECO: A multi-agent modular framework for the simulation of network effects and population dynamics in social sciences, markets & organizations

Web site(s):

http://www-eco.enst-bretagne.fr/~phan/moduleco/english/moduleco00.htm

Address(es):

École Nationale Supérieure des télécommunications de Bretagne, Dpt Economie & ICI-Université Bretagne Occidentale and École Nationale Supérieure des télécommunications de Bretagne, Dpt Informatique.

From the web site:

Moduleco is a "multi-agent" platform, at the crossroads between several disciplines, designed to simulate markets and organizations, social phenomenon and population dynamics.

<u>Framework</u>: NATO C3 Technical Architecture – Volume 1: Management (NATO, 2004a)

Web site(s):

http://nc3ta.nc3a.nato.int/website/book.asp?menuid=15&vs=3

Author(s):

ISSC NATO Open Systems Working Group

From the web site:

NATO C3 Technical Architecture Management: This volume provides the management framework for the development and the configuration control of the NC3TA and includes the general management policy and procedures for implementing the NC3TA in NATO C3 systems development.

Framework: NATO C3 Technical Architecture – Volume 2: Architectural Descriptions and Models (NATO, 2004b)

Web site(s):

http://nc3ta.nc3a.nato.int/website/book.asp?menuid=15&vs=3

Author(s):

ISSC NATO Open Systems Working Group

From the web site:

This volume provides the architectural reference models to help establish the architecture of a C2 system project. This volume is also meant to anticipate the potential use for NATO of new Information Technologies, for instance the emergence of the Service Architecture vs. Component Architecture approach and net-centric technology being pursued by the NNEC Feasibility Study. Supplement 1 provides an overview of Domain Architectures, and Supplement 2 provides an overview of Emerging Technologies.

Framework: NATO C3 Technical Architecture – Volume 3: Base Standards and Profiles (NATO, 2004c)

Web site(s):

http://nc3ta.nc3a.nato.int/website/book.asp?menuid=15&vs=3

Author(s):

ISSC NATO Open Systems Working Group

From the web site:

Base Standards and Profiles: This document contains all current NATO C3 relevant Open System and communications standards and guidance for their use.

<u>Framework</u>: NATO C3 Technical Architecture – Volume 4: NC3 Common Standards Profile (NCSP) (NATO, 2004d)

Web site(s):

http://nc3ta.nc3a.nato.int/website/book.asp?menuid=15&vs=3

Author(s):

ISSC NATO Open Systems Working Group

From the web site:

NC3 Common Standards Profile (NCSP): This document provides the subset of standards critical to interoperability and mandated through the NATO Policy for C3 Systems Interoperability.

<u>Framework</u>: NATO C3 Technical Architecture – Volume 5: NC3 Common Operating Environment (NCOE) (NATO, 2004e)

Web site(s):

http://nc3ta.nc3a.nato.int/website/book.asp?menuid=15&vs=3

Author(s):

ISSC NATO Open Systems Working Group

From the web site:

NC3 Common Operating Environment (NCOE): The NCOE is the NCSP standards-based computing and communications model. Comprised of selected OTS products in its Basket of Products, it provides the structural foundation necessary to build interoperable and open systems.

<u>Framework</u>: The Ministry of Defence Architectural Framework – Technical Handbook (MODAF, 2005)

Web site(s):

http://www.modaf.com/

Author(s):

MODAF Partners

From the web site:

The MOD Architectural Framework (MODAF) is being developed with the intention of providing a rigorous way to specify systems of systems, and is a key enabler to NEC. The framework will predominantly be used for acquisition purposes, and a key driver for its adoption is the need to improve interoperability between systems. However, MODAF could equally well be used to analyse existing, operational systems and better enable their integration with other systems (both new and existing). An architectural framework defines a set of key business and technical information for describing a system of systems architecture. The purpose of an architectural framework is to define the operational context (organizations, locations, processes, information flows, etc.), the system architecture (interfaces, data specifications, protocols, etc.), and the supporting standards and documents that are necessary to describe the system of systems. The information presented in an architectural framework is split into logical groupings – usually known as views. The same system and business elements may be present in more than one view, but the purpose of each view is different and so each provides a different viewpoint on the information. The most mature and widely adopted architectural framework in the defence industry is the US DoD Architectural Framework (DoDAF). This framework has its origins in the C4ISR community and is seen as a fundamental part of the DoD's drive towards Network Centric Warfare. The MODAF is to be based on the DoDAF specification, and will use many of the aspects of DoDAF without alteration. MODAF will also add a number of new views needed to support MOD-specific processes and structures. In addition, other views will be modified, based on lessons learned by users of DoDAF.*

** "Network Enabled Capability" - see CM(IS) NEC Next Steps paper of April 2003.*

Comments from DRDC reviewer:

This improvement of the US DoD-AF provides additional architectural products to deal with many aspects of complexity of System of Systems and of military acquisition. They have renamed DoD-AF's Views to Viewpoints and they have added to DoD-AF's Operational, System, Technical and All views, the Strategic and Acquisition views. MODAF is the first place to go when its time to identify architectural products (and how to use them) in order to model complex huge architectures (System of Systems, capability, etc).

Framework: The Open Group Architecture Framework (TOGAF)

Author(s):

The Open Group

From: http://www.software.org/pub/architecture/togaf.asp

Background

Developed by the Open Group in 1995, this architectural framework was based on the TAFIM, developed by the DoD.

Intent

TOGAF intends to provide a practical, freely available, industry standard method of designing an EA, leveraging all relevant assets in the process. TOGAF is supported by a number of different

architecture consultants, and it is sufficient for an organization to use "as-is" or to adapt as an EA development method for use with other deliverables-focused frameworks.

TOGAF focuses on mission-critical business applications that will use open systems building blocks. The framework embodies the concept of the Enterprise Architecture Continuum (described in Part III of the definition), to reflect different levels of abstraction in an architecture development process. It provides a context for the use of multiple frameworks, models, and architecture assets in conjunction with the TOGAF Architecture Development Method.

Scope

The scope of application for TOGAF includes any organization whose:

- *Products and services are in the business and industry domains*
- *Technical infrastructure is based on open systems building blocks*
- *Definition of EA includes:*
  - *Business Process architecture*
  - *Applications Architecture*
  - *Data Architecture*
  - *Technology Architecture*

Principles

Rather than providing a set of architecture principles, TOGAF explains the rules for developing good principles. Principles may be defined at three levels:

- *Enterprise principles to support business decision making across the entire Enterprise*
- *IT principles guide use of IT resources across the enterprise*
- *Architecture principles govern the architecture development process and the architecture implementation*

TOGAF reccommends a standard way for defining principles. In addition to a definition statement, each principle should have associated rationale and implications statements, both to promote understanding and acceptance of the principles themselves and to support their use in explaining and justifying why specific decisions are made. A standard definition should include a name; a statement of the rule; the rationale with accompanying benefits; and implications of required cost, resources, and activities. See the example from the TOGAF documentation.

Framework: Zachman

Author(s):

John Zachman

From: http://www.software.org/pub/architecture/zachman.asp

Background

In 1987, John Zachman published the Zachman Framework for Enterprise Architecture. He wrote "To keep the business from disintegrating, the concept of information systems architecture is becoming less of an option and more of a necessity." With this belief, he created the ZIFA. This organization is a network of information professionals who understand the value of EA for organizations participating in today's global economy. The mission of ZIFA is to promote the exchange of knowledge and experience in the use, implementation, and advancement of the Zachman Framework for Enterprise Architecture. This framework is used most frequently for business and industry information systems.

Intent

The Zachman Framework is influenced by principles of classical architecture that establish a common vocabulary and set of perspectives for describing complex enterprise systems. This influence is reflected in the set of rules that govern an ordered set of relationships that are balanced and orthogonal. By designing a system according to these rules, the architect can be assured of a design that is clean, easy to understand, balanced, and complete in itself. Zachman's Framework provides the blueprint, or architecture, for an organization's information infrastructure.

Scope

The Zachman Framework describes a holistic model of an enterprise's information infrastructure from six perspectives: planner, owner, designer, builder, subcontractor, and the working system. There is no guidance on sequence, process, or implementation of the framework. The focus is on ensuring that all aspects of an enterprise are well-organized and exhibit clear relationships that will ensure a complete system regardless of the order in which they are established.

Principles

By defining clear architectural design principles, Zachman ensures that any tailored or extended implementation will be equally well built as long as the designer and builder continue to follow the rules.

The major principles that guide the application of the Zachman Framework include:

- *A complete system can be modeled by depicting answers to the questions why, who, what, how, where, and when.*
- *The six perspectives capture all the critical models required for system development.*
- *The constraints for each perspective are additive; those of a lower row are added to those of the rows above to provide a growing number of restrictions.*
- *The columns represent different abstractions in an effort to reduce the complexity of any s ingle model that is built.*
- *The columns have no order.*
- *The model in each column must be unique.*

- *Each row represents a unique perspective.*
- *Each cell is unique.*
- *The inherent logic is recursive.*

Structure

The Zachman Framework is a simple concept with powerful implications. By understanding any particular aspect of a system at any point in its development, system designers c onstruct a tool that can be very useful in making decisions about changes or extensions. The framework contains 6 rows and 6 columns yielding 36 unique cells or aspects. This can be seen in the framework diagram.

Guidance

Most of the prescriptive guidance is given through consulting services contracted through the Zachman Institute. Although no architectural development process is described in publications, there are several observations that can help organizations use the framework more effectively.

The perspectives or rows are very abstract and incomplete near the top but become progressively more detailed and specific moving toward the bottom until an implementation emerges on the last row. This implies that the perspectives can be mapped to a product development life cycle where the top rows are used early on while the bottom rows become more important during the latter phases.

The top two rows are intensively business-oriented and can be expressed in business-oriented vocabularies, while the bottom four rows are in the technical domain.

Although Zachman's models are explicitly procedural, there is no reason why the representation applied to each square in the framework could not be object-oriented. A white paper published in the Rational Edge explains how the Rational Unified Process can be mapped to the Zachman Framework (de Villiers 2001).

Business concepts from the top row must be embedded into business objects and components in the bottom rows. The business concepts can be refined over time, but their relationships should not be changed. Generic software objects and components, along with those from a specific domain repository, can be selected to populate the foundation of the system, but specific application-oriented objects must be designed and integrated to implement the system under development.

Because the order of the columns has no prescribed meaning, they could be rearranged to more closely follow the order of object-oriented design. The requirements are captured in the why column, and the actors are associated with the who column. Because it is generally recommended that service identification precede objects, then the how and what columns can follow. Regardless of the chosen order, note that the columns are related as in the software: the data represent inputs and outputs of the services. The when column can precede the where column if that precedence is more meaningful to a particular software development process, but the point being

made is that the order of the columns can be used to facilitate discussion during object-oriented development. (Graham 1995).

Compliance

The Zachman framework is not a standard written by a professional organization, so no explicit compliance rules have been published. However, if the framework is used in its entirety, and all the given relationship rules are followed, then compliance can be assumed by default. Refer to (Zachman and Sowa 1992) for detailed explanations of the framework rules.

Source

The Zachman Framework can be found at the Zachman Institute.

Tutorial: Managing Complexity and Change Using Architecture Frameworks and Modelling (Martin, 2004)

Author(s):

James N. Martin

Comments from DRDC reviewer:

DRDC reviewer attended this tutorial. The author explains the relative position of the DoD Architecture Framework in the US Department of Defence. The DoD-AF is defined and put in the context of Air Force Enterprise Architecture Framework (AF-EAF) and Federal Enterprise Architecture Framework (FEAF). The concept of architecture level is presented. The author makes then a parallel between the DoD-AF, the Zachman and TOGAF frameworks. The differences between engineering and architecting are presented. Architecting appears to be more an art (nonlinear) while engineering appears to be more a linear science (reductionism). He describe many aspects of the process of architecting and of architecture description themselves. He then describes mission modeling, information modeling, functional modeling and system modeling. DoD-AF products are then completely described. The re-reading of this tutorial brings to mind many solutions that could be used to address complex aspects of Complex Adaptive Systems.

Tutorial: SYS 501: Developing Executable Architecture Using the DoD Architecture Framework (DoDAF) (Dam, 2004)

Author(s):

Dr. Steve Dam

Col. Jim Willis (USAF retired)

Comments from DRDC reviewer:

The authors define what is meant by architecture and the DoD Architecture Framework. They then describe the DoD-AF products and what is missing in the framework. Some techniques and processes used to build architectures are then proposed. They describe some CASE tools that support DoD-AF design and development, how does the framework support interoperability and how to develop executable architecture. The tutorial by itself does not bring new elements but its reading brings to mind many solutions that could be used to address complex aspects of complex systems.

9.2 Other Methodologies, Approaches and Theories

Scientific document: Soft Systems Methodology: An Alternative Approach to Knowledge Elicitation in Complex and Poorly Defined Systems (Finegan, 1994)

Author(s):

Andrew Finegan (rfeadf@minyos.xx.rmit.oz.au)

RMIT Centre for Remote Sensing, Department of Land Information, Royal Melbourne Institute of Technology, GPO Box 2476V, Melbourne Vic. 3001, Australia.

From the document:

The complex systems associated with human activity are often poorly defined. Soft Systems Methodology provides an effective and efficient way to carry out a systems analysis of processes in which technological processes and human activities are interdependent. As an example, it is here used to develop a systems model of technology transfer for applications of remote sensing in Australia. The model identifies rules that are suitable for developing an expert system.

Comments from DRDC reviewer:

The author uses a method called Soft System Methodology to address some aspects of complexity involving human factors and activities. One key basis of this paper is that the standard formal logic of the reductionism or mathematical systems theory alone may be inappropriate for knowledge elicitation. He claims that developing prototypes is of limited success if human factors are poorly defined or not included in analysis. After having described the method, he illustrates its use in a concrete case study.

Scientific document: The Need for Descriptions of a System's Dynamic Behavior on Projects involving the Integration of Large and Complex Systems (Weiss and Glanville, 2002)

Author(s):

Franz Weiss and David Glanville

Raytheon Australia Pty Ltd

From the paper:

This paper *provides the reader with useful signposts to the potential trouble spots and root causes of problems in the integration phase of large projects A project involving the development of a large-scale unprecedented system is a moderately risky venture. Causes of risk occur in each of the phases of development. The causes and their problems are often not addressed during the early project development phases, but inevitably remanifest themselves in the realities of the integration phase. Thus the integration phase always seems to have more than its fair share of project problems. There are many causes for the problems in the integration phase. This paper postulates that one of the main causes is the omission of a description of the system's dynamic behavior from the design baselines. A static description of the design is usually all that is provided. This description alone leads to inadequate integration plans, techniques, test tools, skill sets and knowledge. This paper suggests some reasons why the description of dynamic behavior is not produced and the reaction of the project's staff to this absence. It then describes the negative effects of not having a description of the system's dynamic behavior on the integration task. Finally, some standards and literature that should prevent these difficulties are identified.*

Comments from DRDC reviewer

This paper lists many problems that may arise in large development programs when there are no dynamical views of the systems to be developed. The paper also suggests many international standards to remediate to this problem. The paper was not made to address complexity problems but its reading may be helpful.

<u>Scientific document</u>: Cross-entropy and rare events for maximal cut and partition problems (Rubinstein, 2002)

Author(s):

Reuven Y. Rubinstein

Technion---Israel Institute of Technology, Haifa, Israel and The Institute of Statistical Mathematics, Tokyo, Japan.

From the document:

We show how to solve the maximal cut and partition problems using a randomized algorithm based on the cross-entropy method. For the maximal cut problem, the proposed algorithm employs an auxiliary Bernoulli distribution, which transforms the original deterministic network into an associated stochastic one, called the associated stochastic network (ASN). Each iteration of the randomized algorithm for the ASN involves the following two phases:(1) Generation of random cuts using a multidimensional Ber(p) distribution and calculation of the associated cut lengths (objective functions) and some related quantities, such as rare-event probabilities.(2) Updating the parameter vector p on the basis of the data collected in the first phase.We show that the Ber(p) distribution converges in distribution to a degenerated one, Ber(pd), pd* = (pd,1,...,pd,n) in the sense that someelements of pd*, will be unities and the rest zeros. The unity elements of pd* uniquely define a cut which will be taken as the estimate of the maximal cut. A similar approach is used for the partition problem. Supporting numerical results are given*

as well. Our numerical studies suggest that for the maximal cut and partition problems the proposed algorithm typically has polynomial complexity in the size of the network.

Scientific document: Assessing the Reliability of Socio-Technical Systems (Gregoriades et al., 2003)

Author(s):

Andreas Gregoriades (andreas@co.umist.ac.uk)
Alistair Sutcliffe (a.g.sutcliffe@co.umist.ac.uk)
Jae-Eun Shin (jeshin@co.umist.ac.uk)

Centre of HCI, UMIST, Manchester, M60 1QD

From the document:

This paper presents a Bayesian belief network (BBN) approach for socio technical system reliability assessment. A human error model (BBN) quantifies error influences arising from user knowledge, ability and task environment, combined with factors describing the complexity of user action and user interface quality. System reliability evaluation is achieved by the Scenario Reliability analyser tool, which enables the iterative manipulation of the human error model according to high-level scenarios.

Scientific document: Diagnozing Reliability Problems in Socio-technical Systems: A Visualization Approach (Gregoriades and Sutclife, 2003)

Author(s):

Andreas Gregoriades (andreas@co.umist.ac.uk)
Alistair Sutcliffe (a.g.sutcliffe@co.umist.ac.uk)

Centre of HCI, UMIST, Manchester, M60 1QD

Scientific document: The Cross-Entropy Method: A Unified Approach to Combinatorial Optimization, Monte-Carlo Simulation and Machine Learning (Rubenstein, 2004)

Author(s):

Reuven Y. Rubenstein

From Amazon.com:

The cross-entropy (CE) method is one of the most significant developments in stochastic optimization and simulation in recent years. This book explains in detail how and why the CE method works. The CE method involves an iterative procedure where each iteration can be broken down into two phases: (a) generate a random data sample (trajectories, vectors, etc.) according to a specified mechanism; (b) update the parameters of the random mechanism based on this data in order to produce a "better" sample in the next iteration. The simplicity and

versatility of the method is illustrated via a diverse collection of optimization and estimation problems. The book is aimed at a broad audience of engineers, computer scientists, mathematicians, statisticians and in general anyone, theorist or practitioner, who is interested in fast simulation, including rare-event probability estimation, efficient combinatorial and continuous multi-extremal optimization, and machine learning algorithms. Reuven Y. Rubinstein is the Milford Bohm Professor of Management at the Faculty of Industrial Engineering and Management at the Technion (Israel Institute of Technology). His primary areas of interest are stochastic modelling, applied probability, and simulation. He has written over 100 articles and has published five books. He is the pioneer of the well-known score-function and cross-entropy methods. Dirk P. Kroese is an expert on the cross-entropy method. He has published close to 40 papers in a wide range of subjects in applied probability and simulation. He is on the editorial board of Methodology and Computing in Applied Probability and is Guest Editor of the Annals of Operations Research. He has held research and teaching positions at Princeton University and The University of Melbourne, and is currently working at the Department of Mathematics of The University of Queensland. From the reviews: "Rarely have I seen such a dense and straight to the point pedagogical monograph on such a modern subject. This excellent book, on the simulated cross-entropy method (CEM) pioneered by one of the authors (Rubinstein), is very well written..." Computing Reviews, Stochastic Programming November, 2004 "...I wholeheartedly recommend this book to anybody who is interested in stochastic optimization or simulation-based performance analysis of stochastic systems." Gazette of the Australian Mathematical Society, vol. 32 (3) 2005 "This book describes the cross-entropy method for a range of optimization problems. … It is a substantial contribution to stochastic optimization and more generally to the stochastic numerical methods theory." (V.V.Fedorov, Short Book Reviews, Vol. 25 (1), 2005) "Since the CE method is a young and developing field, there is no book available in this area where the two authors are the pioneers. Therefore, it is quite a unique book and it may become a classic reference in the CE method literature." Technometrics, February 2005.

Scientific document: On Engineering and Emergence (Fromm, 2006)

Author(s):

Jochen Fromm (fromm@vs.uni-kassel.de)

Distributed Systems Group, Kassel University, EECS Department for Electrical Engineering and Computer Science, Wilhelmshöher Allee 73, D-34121 Kassel, Germany

http://www.vs.uni-kassel.de/~fromm/

From the document:

The engineering and design of self-organizing systems with emergent properties is a long-standing problem in the field of complex and distributed systems, for example in the engineering of self-organizing Multi-Agent Systems. We examine the question if a general solution to the MML problem of AOSE and ESOA exists and if a formal approach is possible. The problem of combining engineering with emergence – to find a simple rule for a complex pattern – equals the problem of science in general. Therefore the answers are similar, and the scientific method is the general solution to the problem of engineering complex systems.

<u>Book</u>: Graph Theory and Its Applications (Gross and Yellen , 2006)

Author(s):

Jonathan L. Gross and Jay Yellen

From Amazon.com:

Already the most widely used textbook on graph theory, Gross and Yellen's Graph Theory and Its Applications enhances its appeal with the release of this revised and expanded second edition. The superior explanations, original applications, and abundance of study problems that positioned it as the preferred selection of classroom professors worldwide are still to be found. Nearly 200 pages have been added for the second edition including two new chapters; hundreds of new exercises, mostly non-routine; now has solutions with actual drawings and hints to selected exercises; extensive revision and reorganization of more than half of the existing chapters.

<u>Book</u>: Turing's Connectionism: An Investigation of Neural Network Architectures (Teuscher , 2001)

Author(s):

Christof Teuscher

From Amazon.com:

Turing's connectionism provides a detailed and in-depth analysis of Turing's almost forgotten ideas on connectionist machines. In a little known paper entitled "Intelligent Machinery", Turing already investigated connectionist models as early as 1948. Unfortunately, his work was dismissed by his employer as a "schoolboy essay" and went unpublished until 1968, 14 years after his death.In this book, Christof Teuscher analyzes all aspects of Turing's "unorganized machines". Turing himself also proposed a sort of genetic algorithm to train the networks. This idea has been resumed by the author and genetic algorithms are used to build and train Turing's unorganized machines. Teuscher's work starts from Turing's initial ideas, but importantly goes beyond them. Many new kinds of machines and new aspects are considered, e.g., hardware implementation, analysis of the complex dynamics of the networks, hypercomputation, and learning algorithms.

<u>Book</u>: Topological Graph Theory (Gross and Tucker, 2001)

Author(s):

Jonathan L. Gross and Thomas W. Tucker

From Amazon.com:

Clear, comprehensive introduction emphasizes graph imbedding but also covers thoroughly the connections between topological graph theory and other areas of mathematics. Discussion of

imbeddings into surfaces is combined with a complete proof of the classification of closed surfaces. Authors explore the role of voltage graphs in the derivation of genus formulas, explain the Ringel-Youngs theorem—a proof that revolutionized the field of graph theory—and examine the genus of a group, including imbeddings of Cayley graphs. 1987 edition. Many figures.

<u>Book</u>: Fuzzy Logic with Engineering Applications, 2nd Edition (Ross, 2004)

Author(s):

Timothy J. Ross

From Amazon.com

Fuzzy logic is a simple phrase that actually refers to a large subject dealing with a set of methods to characterize and quantify uncertainty in engineering systems that arise from ambiguity, imprecision, fuzziness, and lack of knowledge. This 15-chapter textbook remains the only major text that can be used for both undergraduate and graduate classroom instruction in this technology field. The first 8 chapters of the text cover fundamental materials useful in characterizing various forms of uncertainty and in developing the methods to quantify these uncertainties. Four chapters present specific case studies in decision making, classification and pattern recognition, control, simulation, and fuzzy arithmetic. There is one chapter on miscellaneous applications of fuzzy logic, one chapter on new rule-reduction techniques, and the final chapter presents material on other uncertainty theories with examples using evidence theory, possibility theory, and probability theory. Key features include: end-of-chapter references and exercise problems solutions to selected exercise problems an accompanying online instructors' solution manual accompanying online software and updates examples of applications in most engineering disciplines: civil, chemical, mechanical, electrical, and computer science and engineering See URL:www.wileyeurope.com/go/fuzzylogic for all online material. This book will appeal to senior undergraduate and graduate students in engineering, and to graduate students in many other scientific fields. Practitioners in control theory, classification, systems integration and systems modeling and operations research application will also find this a useful text.

<u>Web Site</u>: Group Method of Data Handling (GMDH)

Web site(s):

http://www.gmdh.net/

From http://www.gmdh.net/ web site:

Group Method of Data Handling was applied in a great variety of areas for data mining and knowledge discovery, forecasting and systems modeling, optimization and pattern recognition. Inductive GMDH algorithms give possibility to find automatically interrelations in data, to select optimal structure of model or network and to increase the accuracy of existing algorithms. This original self-organizing approach is substantially different from deductive methods used commonly for modeling. It has inductive nature - it finds the best solution by sorting-out of possible variants. By sorting of different solutions GMDH networks aims to minimize the influence of the author on the results of modeling. Computer itself finds the structure of the model*

and the laws which act in the system. Group Method of Data Handling is a set of several algorithms for different problems solution. It consists of parametric, clusterization, analogues complexing, rebinarization and probability algorithms. This inductive approach is based on sorting-out of gradually complicated models and selection of the best solution by minimum of external criterion characteristic. Not only polynomials but also non-linear, probabilistic functions or clusterizations are used as basic models. GMDH approach can be useful because:

- *The optimal complexity of model structure is found, adequate to level of noise in data sample. For real problems solution with noised or short data, simplified forecasting models are more accurate.*
- *The number of layers and neurons in hidden layers, model structure and other optimal NN parameters are determined automatically.*
- *It guarantees that the most accurate or unbiased models will be found - method doesn't miss the best solution during sorting of all variants (in given class of functions).*
- *As input variables are used any non-linear functions or features, which can influence the output variable.*
- *It automatically finds interpretable relationships in data and selects effective input variables.*
- *GMDH sorting algorithms are rather simple for programming.*
- *TMNN neural nets are used to increase the accuracy of another modelling algorithms.*
- *Method uses information directly from data sample and minimizes influence of apriori author assumptions about results of modeling.*
- *Approach gives possibility to find unbiased physical model of object (law or clusterization) - one and the same for future samples.*

Since 1968 many investigations and applications of GMDH were conducted in many countries. It was implemented in many commercial software products.

Other related web addresses are:

http://www.gmdh.net/articles/index.html#theory

http://www.gmdh.net/GMDH_exa.htm

http://www.gmdh.net/GMDH_his.htm

http://www.knowledgeminer.net/book/preface.htm

9.3 Abstraction Languages and Tools

9.3.1 Modeling Languages

Abstraction language: Business Process Modeling Notation (BPMN)

Web site(s):

http://www.bpmn.org/

http://www.igrafx.com/solutions/bpmn/

http://www.ebpml.org/bpmn.htm

Description from http://www.ebpml.org/bpmn.htm:

The goal of BPMN is to provide a business process modeling notation that is readily usable by business analysts, technical developers and business people that manage and monitor these processes. One of the goal of BPMN is also to be able to generate execution definitions (BPEL4WS) that will be used to implement the business processes. As such BPMN positions itself as a bridge between modeling and execution and between people that run the business and implementers of systems that support the business. BPMN allows us to create a Business Process Diagram which represent the activities of the business process and the flow controls that define the order in which they are performed. BPMN has tried to find the best tradeoff possible between an intuitive notation, using familiar constructs, and a complete set of business rules common to the business processes.

Abstraction language: Integrated Definition Methods-0 (IDEF0)

Web site(s):

http://www.idef.com/idef0.html

Description from web site:

IDEFØ is a method designed to model the decisions, actions, and activities of an organization or system. IDEFØ was derived from a well-established graphical language, the Structured Analysis and Design Technique (SADT). The United States Air Force commissioned the developers of SADT to develop a function modeling method for analyzing and communicating the functional perspective of a system. Effective IDEFØ models help to organize the analysis of a system and to promote good communication between the analyst and the customer. IDEFØ is useful in establishing the scope of an analysis, especially for a functional analysis. As a communication tool, IDEFØ enhances domain expert involvement and consensus decision-making through simplified graphical devices. As an analysis tool, IDEFØ assists the modeler in identifying what functions are performed, what is needed to perform those functions, what the current system does right, and what the current system does wrong. Thus, IDEFØ models are often created as one of the first tasks of a system development effort.

Abstraction language: Integrated Definition Methods-1x (IDEF1x)

Web site(s):

http://www.idef.com/IDEF1X.html

Description from web site:

IDEF1X is a method for designing relational databases with a syntax designed to support the semantic constructs necessary in developing a conceptual schema. A conceptual schema is a single integrated definition of the enterprise data that is unbiased toward any single application and independent of its access and physical storage. Because it is a design method, IDEF1X is not particularly suited to serve as an AS-IS analysis tool, although it is often used in that capacity as an alternative to IDEF1. IDEF1X is most useful for logical database design after the information requirements are known and the decision to implement a relational database has been made. Hence, the IDEF1X system perspective is focused on the actual data elements in a relational database. If the target system is not a relational system, for example, an object-oriented system, IDEF1X is not the best method.

Abstraction language: IDEF Related Tools

Web site(s):

http://www.pera.net/Tools/Idef_tools.html

Abstraction language: Petri Nets

Web site(s):

http://www.informatik.uni-hamburg.de/TGI/PetriNets/

Description from Wikipedia (http://en.wikipedia.org/wiki/Petri_net):

A Petri net (also known as a place/transition net or P/T net) is one of several mathematical representations of discrete distributed systems. As a modeling language, it graphically depicts the structure of a distributed system as a directed bipartite graph with annotations. As such, a Petri net has place nodes, transition nodes, and directed arcs connecting places with transitions. Petri nets were invented in 1962 by Carl Adam Petri in his PhD thesis.

Tool: Petri Nets Related Tools

Web site(s):

http://www.informatik.uni-hamburg.de/TGI/PetriNets/

Abstraction language: SysML

Web site(s):

http://www.sysml.org/

Description from OMG web site (http://www.sysml.org/):

SysML is a domain-specific modeling language for systems engineering applications. It supports the specification, analysis, design, verification and validation of a broad range of systems and systems-of-systems. These systems may include hardware, software, information, processes, personnel, and facilities. The first complete version of SysML, SysML v. 1.0, is now available for download from the Specifications page of this web. See for yourself why this new domain specific language is smaller and better suited for systems engineering applications than the Unified Modeling Language™ (UML™) on which it is based. (SysML is currently specified as a UML 2.0 Profile, or customization.)

Abstraction language: UML

Web site(s):

http://www.uml.org/

Description from OMG web site (http://www.omg.org/gettingstarted/what_is_uml.htm):

The OMG's Unified Modeling Language™ (UML®) helps you specify, visualize, and document models of software systems, including their structure and design, in a way that meets all of these requirements. (You can use UML for business modeling and modeling of other non-software systems too.) Using any one of the large number of UML-based tools on the market, you can analyze your future application's requirements and design a solution that meets them, representing the results using UML 2.0's thirteen standard diagram types.

Tool: Workflow Tools

Web site(s):

http://www.waria.com/

http://www.wfmc.org/

9.3.2 Simulation Languages

Simulation language: GPSS

Web site(s):

http://www.csd.uwo.ca/staff/dave/gpss.html

Description:

GPSS is a highly structures, special-purpose simulation programming language based on the process-interaction approach and oriented toward queuing systems. A block diagram provides a convenient way to describe the system being simulated. There are over 40 standard blocks in GPSS. Entities called transactions may be viewed as flowing through the block diagram. Blocks represent events, delays, and other actions that affect transaction flow. GPSS can be used to model any situation where transactions (entities, customers, units of traffic) are flowing through a system. The block diagram is converted to block statements, control statements are added, and the result is a GPSS model.

Simulation language: CSIM

Web site(s):

http://www.mesquite.com/

http://www.atl.lmco.com/projects/csim/simulator/csim_doc.html#anch_1.0

Description:

CSIM is a system for using the C or C++ language for modeling, along with a rich library of predefined objects to support process-oriented simulation modeling. CSIM is fast, owing to careful implementation and being a compiled language.

9.3.3 Complexity Related Tools

Tool: ECHO

Web site(s):

http://www.santafe.edu/projects/echo/echo.html

http://www.santafe.edu/projects/echo/how-to/how-to.html

Description from web site:

Echo is a simulation tool developed to investigate mechanisms which regulate diversity and information-processing in systems comprised of many interacting adaptive agents, or complex adaptive systems (CAS). Echo agents interact via combat, trade and mating and develop strategies to ensure survival in resource-limited environments. Individual genotypes encode rules for interactions. In a typical simulation, populations of these genomes evolve interaction networks which regulate the flow of resources. Resulting networks resemble species communities in ecological systems. Flexibly defined parameters and initial conditions enable researchers to conduct a range of "what-if" experiments.

Tool: OntoSpace

Sources:

Ontonix – Complex Systems Management

Ontonix LLC, 29024 Hearthstone Drive, Novi, MI 48377-2724, U.S.A., Phone: +1-248-686-2100

Web site(s):

http://www.ontonix.com/

Description from http://www.deskeng.com/ web site:

OntoSpace, a complexity assessment and management tool for the analysis of complex systems, of their structure, and behavioral patterns, is the flagship product of Ontonix LLC (New York, NY), a technology company that also provides uncertainty and complexity management services. The company believes that OntoSpace is the first commercial application for practical complexity management. The key to datum that unlocks the concept underlying OntoSpace is that it gives you the ability to unveil the non-intuitive behavior of systems. OntoSpace extends Monte Carlo techniques beyond simple computations of performance scatter or probabilities of failure into the realm of robustness and complexity analyses. It provides rational measures of both robustness and complexity, and it shows how these fundamental attributes of any system are intimately linked. OntoSpace makes system complexity a component of your design and decision-making processes enabling you to manage it. The software works with data originating from computer models, sensors, or historical records. It generates intuitive cognitive maps that link together rules and illustrate the possible states in which the system may find itself functioning. With OntoSpace, you can obtain a set of system modes that represent the possible behavioral patterns the system can exhibit over its entire operational range. OntoSpace can quantify the complexity of the system in each mode as well as quantify the complexity of the entire system, thus enabling you to understand your system's structure and topology. OntoSpace enables you to identify pathologies in the system, and identify and analyze outliers OntoSpace can identify hubs (i.e., critical elements) for each mode, which, if lost, may cause system collapse, such as a keystone species in an ecosystem. OntoSpace can also be used to perform what-if studies and assess overall system vulnerability and risk. Here's a partial list of the types of questions OntoSpace can be used for:

- *Solving complex problems involving uncertainty or uncertain environments*
- *Managing risk and liability such as warranty or re-calls*
- *Determining where the fragility (i.e., vulnerability) of a system is concentrated*
- *Extracting knowledge out of massive amounts of data*
- *Monitoring complex systems or plants*
- *Monitoring and managing intricate time-domain scenarios such as battlefields, power grids, and air traffic*
- *Running stochastic simulations and extracting knowledge from the results*

OntoSpace is application-independent, said to be easy to use, and does not require vast mathematical training or knowledge of statistics.

9.3.4 Multi-agent Programming (MAP) Tools

Tool: AgentSheets

Sources:

Alexander Repenning, Andri Ioannidou and John Zola AgentSheets: End User Programmable Simulations Journal of Artificial Societies and Social Simulations. Vol. 3, No. 3. *http://jasss.soc.surrey.ac.uk/3/3/forum/1.html*

Joaquim Carvalho Using AgentSheets to teach simulation to undergraduate students Journal of Artificial Societies and Social Simulations. Vol. 3, No. 3. *http://jasss.soc.surrey.ac.uk/3/3/forum/2.html*

Web site(s):

http://www.agentsheets.com/

Description from web site:

AgentSheets is a revolutionary authoring tool that allows non-programmers to create agents with behaviors and missions, teach agents to react to information and process it in personalized ways, and combine agents to create sophisticated interactive simulations and models. Our customers use AgentSheets to create interactive games, virtual worlds, training simulations, information gathering and personalizing agents, and other interactive content. Users can interact with their agents via multiple modalities such as mouse and keyboard input, speech recognition and synthesis, music, and video. AgentSheets features our unique Visual AgenTalk® tactile and rule-based language to create, modify, and customize agent behavior. The Ristretto® generator technology incorporated in AgentSheets turns a simulation directly into an interactive Java applet embedded in a Web page. AgentSheets enables users to deliver content on PDAs (such as iPAQ), cell phones, Web browsers, and desktop machines. Content can take the form of Java applets, JavaBeans or Macromedia Flash movies. AgentSheets runs both on Windows platform and Macintosh platforms.

Comment from Julie Dugdale (http://www.irit.fr/COSI/training/evaluationoftools/Evaluation-Of-Simulation-Tools.htm):

AgentSheets is an agent based simulation tool which is based on a spreadsheet approach. Instead of the cells of the spreadsheet grid being occupied by numbers they are instead occupied by agents. The simulations then takes place on the grid on which the agents live. AgentSheets is specifically aimed at non-programmers and as a consequence it is very simple to use. AgentSheets uses the visual programming paradigm meaning that there is no actual text based coding and all the development is done via a graphical interface (dragging and dropping elements from toolboxes, etc.). Indeed, the ease of use of AgentSheets is its greatest advantage. Agents are created in a window called a 'gallery' and have an associated behaviour specified by sets of rules (called methods) and events.

Tool: Ascape

Sources:

Ascape Home Page at the Brookings Institute including papers and model applets. *http://www.brook.edu/es/dynamics/models/ascape/*

Presentation Slides on Ascape by Miles Parker *http://www.brook.edu/es/dynamics/models/ascape/UChicago/tsld001.htm*

An article by Miles Parker in JASSS entitled 'What is Ascape and why should you care?' Published January 2001 *http://jasss.soc.surrey.ac.uk/4/1/5.html*

Louis Foucart's article: 'A Small Multi Agent Systems Review' which covers Ascape *http://geneura.ugr.es/~louis/masReview.html*

Web site(s):

http://www.brook.edu/es/dynamics/models/ascape/

Description from web site:

Ascape is written entirely in Java and should work on any Java capable machine. In most cases you should be able to simply download and run the installer and begin exploring Ascape. For more information, see the Read Me. To develop Ascape models you will need to have (or acquire) a working knowledge of Java programming. Please note that we do not provide direct support for Ascape; if you have questions or need help, consider joining the Ascape mailing list, which we maintain and monitor. Please let us know what you think; we welcome your comments and suggestions for improvements.

Comment from Julie Dugdale (http://www.irit.fr/COSI/training/evaluationoftools/Evaluation-Of-Simulation-Tools.htm):

Ascape is a framework for developing and analysing agent based models which was developed by the Brookings Institute (The Center on Social and Economics Dynamics which developed the well-known Sugarscape simulation). Ascape follows some of the ideas behind Swarm (e.g. agents existing within scapes which can themselves be treated as an agent). However, it is slightly easier to develop models with Ascape than with Swarm. Indeed, it is intended to allow non-programmers to develop quite complex simulations by providing a range of end-user tools (e.g. facilities to gather statistics of the running simulation, tools for creating graphs, etc.).

Tool: Breve

Web site(s):

http://www.spiderland.org/breve/

Description from web site:

Breve is a free, open-source software package which makes it easy to build 3D simulations of decentralized systems and artificial life. Users define the behaviors of agents in a 3D world and observe how they interact. breve includes physical simulation and collision detection so you can simulate realistic creatures, and an OpenGL display engine so you can visualize your simulated worlds.

Tool: JADE

Web site(s):

http://jade.tilab.com/

Description from web site:

JADE (Java Agent DEvelopment Framework) is a software Framework fully implemented in Java language. It simplifies the implementation of multi-agent systems through a middle-ware that complies with the FIPA specifications and through a set of graphical tools that supports the debugging and deployment phases. The agent platform can be distributed across machines (which not even need to share the same OS) and the configuration can be controlled via a remote GUI. The configuration can be even changed at run-time by moving agents from one machine to another one, as and when required. JADE is completely implemented in Java language and the minimal system requirement is the version 1.4 of JAVA (the run time environment or the JDK). The synergy between the JADE platform and the LEAP libraries allows to obtain a FIPA-compliant agent platform with reduced footprint and compatibility with mobile Java environments down to J2ME-CLDC MIDP 1.0. The LEAP libraries have been developed with the collaboration of the LEAP project and can be downloaded as an add-on of JADE from this same Web site. JADE is free software and is distributed by Telecom Italia, the copyright holder, in open source software under the terms of the LGPL (Lesser General Public License Version 2). Since May 2003, a JADE Board has been created that supervisions the management of the JADE Project. Currently the JADE Board lists 5members: Telecom Italia , Motorola, Whitestein Technologies AG., Profactor GmbH, and France Telecom R&D.

Tool: The Java Agent Framework (JAF)

Web site(s):

http://jade.tilab.com/

Description from web site:

An architecture was needed for the agents working within the Mass environment which effectively isolated the agent-dependent behavior logic from the underlying support code which would be common to all of the agents in the simulation. One goal of the framework was therefore to allow an agent's behavioral logic to perform without the knowledge that it was operating under simulated conditions, e.g. a problem solving component in a simulated agent would be the same as in a real agent of the same type. The framework also needed to be flexible and extensible, and yet maintain separation between mutually dependent functional areas to the extent that one could be replaced without modifying the other. To satisfy these requirements, a component-based

design, the Java Agent Framework (JAF), was created. Component based architectures are a relatively new arrival in the field of software engineering which build upon the notion of object-oriented design. They attempt to effectively encapsulate the functionality of an object while respecting interface conventions, thereby enabling the creation of stand alone applications by simply plugging together groups of components. This paradigm is ideal for our agent framework, because it permits the creation of a number of common-use components, which other agent-dependent components can easily make use of.

Tool: Java Agent-based Simulation Library (JAS)

Web site(s):

http://jaslibrary.sourceforge.net/

Description from web site:

JAS is a Java toolkit for creating agent-based simulations. It features a discrete-event time engine, statistical probes with Hypersonic database built-in storage capability, Neural Networks and Genetic Algorithms packages, graph support for Social Netwok Analysis.

Tool: The Madkit Project

Web site(s):

http://www.madkit.org/

Description from web site:

MadKit is a modular and scalable multiagent platform written in Java and built upon the AGR (Agent/Group/Role) organizational model: agents are situated in groups and play roles. MadKit allows high heterogeneity in agent architectures and communication languages, and various customizations. MadKit communication is based on a peer to peer mechanism, and allows developpers to quickly develop distributed applications using multiagent principles. Agents in MadKit may be programmed in Java, Scheme (Kawa), Jess (rule based engine) or BeanShell. Other script language may be easily added. MadKit comes with a full set of facilities and agents for launching, displaying, developping and monitoring agents and organisations.

Tool: Multi-Agent Modelling Language (MAML)

Sources:

The MAML Home Page including MAML User manual, examples, papers, etc. *http://www.syslab.ceu.hu/maml/maml.html*

Slides describing MAML which was presented at SwamFest'99 *http://www.syslab.ceu.hu/maml/SwarmFest99/*.

http://www.brook.edu/es/dynamics/models/ascape/

Comment from Julie Dugdale (http://www.irit.fr/COSI/training/evaluationoftools/Evaluation-Of-Simulation-Tools.htm):

MAML was developed by the Complex Adaptive Systems Lab. at the Central European University in Hungary. The language was initially developed to help social science students with limited programming experience create agent based models quickly. The ultimate goal of the project is to develop an easy to use environment (complete with a graphical interface). However, the present version of MAML is, as the name suggests, a programming language and not an environment. MAML actually sits on top of Swarm and is intended to make Swarm easier to use by providing macro-keywords that define the structure of the simulator and access the Swarm libraries. MAML works at a higher level of abstraction than Swarm with clearer constructs. However, in addition to learning MAML, the developer would need to know Objective C and also Swarm. This point currently limits MAMLs usefulness to unexperienced programmers. Indeed, experienced programmers may actually prefer the added functionality of Swarm and the additional resources available. Programming using MAML requires the developer to create text files using a text editor since there is no developer's interface to MAML. Since MAML accesses the Swarm libraries, the interface of the developed simulation model is very similar as to what would appear if Swarm were used. With respect to MAMLs suitability to social science simulation, most of the effort in developing MAML has been devoted to simplifying the programming effort rather than providing facilities specifically geared towards modelling social science mechanisms.

Tool: MASON

Web site(s):

http://cs.gmu.edu/~eclab/projects/mason/

Description from web site:

MASON is a fast discrete-event multiagent simulation library core in Java, designed to be the foundation for large custom-purpose Java simulations, and also to provide more than enough functionality for many lightweight simulation needs. MASON contains both a model library and an optional suite of visualization tools in 2D and 3D. MASON is a joint effort between George Mason University's ECLab Evolutionary Computation Laboratory and the GMU Center for Social Complexity, and was designed by Sean Luke, Gabriel Catalin Balan, and Liviu Panait, with help from Claudio Cioffi-Revilla, Sean Paus, Daniel Kuebrich, and Keith Sullivan. MASON Stands for Multi-Agent Simulator Of Neighborhoods... or Networks... or something...

Tool: NetLogo

Web site(s):

http://ccl.northwestern.edu/netlogo/docs/

Description from web site:

NetLogo is a programmable modeling environment for simulating natural and social phenomena. It is particularly well suited for modeling complex systems developing over time. Modelers can

give instructions to hundreds or thousands of independent "agents" all operating concurrently. This makes it possible to explore the connection between the micro-level behavior of individuals and the macro-level patterns that emerge from the interaction of many individuals. NetLogo is the next generation of the series of multi-agent modeling languages that started with StarLogo. It builds off the functionality of our product StarLogoT and adds significant new features and a redesigned language and user interface. NetLogo is written in Java so it can run on all major platforms (Mac, Windows, Linux, et al). It is run as a standalone application. Individual models can be run as Java applets inside a web browser.

Tool: Open Agent Architecture

Web site(s):

http://www.ai.sri.com/~oaa/

Description from web site:

A framework for integrating a community of heterogeneous software agents in a distributed environment.

Tool: RePast

Sources:

RePast Home Page *http://repast.sourceforge.net/*

Louis Foucart's article: 'A Small Multi Agent Systems Review' which covers RePast *http://geneura.ugr.es/~louis/masReview.html*.

Web site(s):

http://repast.sourceforge.net/

http://www.irit.fr/COSI/training/evaluationoftools/Evaluation-Of-RePast.htm

Description from web site:

The Recursive Porous Agent Simulation Toolkit (Repast) is one of several agent modeling toolkits that are available. Repast borrows many concepts from the Swarm agent-based modeling toolkit. Repast is differentiated from Swarm since Repast has multiple pure implementations in several languages and built-in adaptive features such as genetic algorithms and regression. For reviews of Swarm, Repast, and other agent-modeling toolkits, see the 2002 survey by Serenko and Detlor, the 2002 survey by Gilbert and Bankes, and the 2003 toolkit review by Tobias and Hofmann. Repast is a free open source toolkit that was originally developed by Sallach, Collier, Howe, North and others. Repast was created at the University of Chicago. Subsequently, it has been maintained by organizations such as Argonne National Laboratory. Repast is now managed by the non-profit volunteer Repast Organization for Architecture and Development (ROAD). ROAD is lead by a board of directors that includes members from a wide range of government, academic

and industrial organizations. The Repast system, including the source code, is available directly from the web. Repast seeks to support the development of extremely flexible models of living social agents, but is not limited to modeling living social entities alone.

Comment from Julie Dugdale (http://www.irit.fr/COSI/training/evaluationoftools/Evaluation-Of-Simulation-Tools.htm):

Repast was developed at the University of Chicigo's Social Science Research Computing lab specifically for creating agent based simulations. It is very 'Swarm-like', both in philosophy and appearance and like Swarm it provides a library of code for creating, running, displaying and collecting data from simulations.

Tool: Multi-Agent Simulation Environment

Web site(s):

http://www.simsesam.de/

Description from web site:

SeSAm (Shell for Simulated Agent Systems) provides a generic environment for modelling and experimenting with agent-based simulation. We specially focused on providing a tool for the easy construction of complex models, which include dynamic interdependecies or emergent behaviour. SeSAm provides: Easy visual agent modelling, Flexible environment and situation definition, The whole power of a programming language, Integrated graphical simulation analysis, Distribution of simulation runs in your LAN, and many further features. SeSAm agents consist of a body, that contains a set of state variables and a behaviour that is implemented in form of UML-like diagram. Based on an extensive number of primitive components, a user is able to design a simulation graphically without knowing the syntax of a traditional programming language. The model specification is executable in the same environment and the dynamics of this simulation may be observed. As there are freely configurable instruments for gathering data and scripting options for constructing simulation experiments, SeSAm is a highly valuable tool for MAS simulations especially for complex models with flexible agent behaviour and interactions.

Tool: Stricly Declarative Modelling Language (SMDL)

Sources:

The main resource is the SDML Home page at Manchester Metropolitan University (the site includes tutorials, discussion papers, SDML download facility and mailing lists). *http://www.cpm.mmu.ac.uk/sdml/*

The SDML Beginners tutorial is available at: *http://www.cpm.mmu.ac.uk/sdml/intro/html/sdml_tut_1.html*

http://repast.sourceforge.net/

Description from web site:

SDML is a modelling language with the following features:

- *Knowledge is represented on rulebases and databases*
- *All knowledge is declarative*
- *Models can be constructed from many interacting agents*
- *Complex agents can be composed of simpler ones*
- *Object-oriented facilities, such as multiple inheritance, are provided*
- *Temporal facilities are provided, including different levels of time*
- *Rules can be fired using forward and backward chaining*

SDML is implemented in Smalltalk by Steve Wallis in consultation with other members of the Centre for Policy Modelling. It evolved from a non-declarative modelling language implemented by Scott Moss.

Comment from Julie Dugdale (http://www.irit.fr/COSI/training/evaluationoftools/Evaluation-Of-Simulation-Tools.htm):

SDML is not an environment but a declarative programming language having object oriented features and being logic based. Knowledge is represented in rulebases and databases and the main reasoning mechanism used is forward and backward chaining. Agents may be assigned rules which determine their behaviour and which can be shared with other agents. The latter point is possible due to the object-oriented features of SDML. The fact that it is strongly grounded in logic allows formal proofs of the completeness of the model to be constructed. Programming is conducted in SDML via a series of windows ('An introduction to SDML, a short course for beginners' on the SDML Home Page gives a good feel of the interface). Sophisticated simulations may be built using SDML involving complex interacting organisations, deeply nested levels of agents, and the ability for agents to possess limited cognitive abilities. However, as the developers admit, the language has a steep learning curve. Whilst SDML was specifically developed for building simulations in the social sciences, most of the available models are concerned with economic and market modelling. Indeed, apart from the SDML Home Page at Manchester Metropolitan University, there are very few examples of simulations using SDML. SDML does however provide features useful in modelling cognitive social agents. There is no inherent theory of cognition implemented in SDML so any agent cognition is represented as sets of rules. Communication between agents is achieved via databases: the result of a fired rule is written to an agent's database which may be accessed via another agent. The accessibility of one agent's database to another agent's database can be restricted by assigning a status to the rule's clause (e.g. private or public). Agents may also evaluate each other as being possible 'collaborators' and endorse other agents as being a reliable, unrealiable, successful, or unsuccessful collaborator. SDML is available for MS Windows 3.1/95/98/2000/NT, Linux, Intel, PowerMac, Unix ADUX/AIX/HPUX/SGI/Solaris.

Tool: SimAgent TOOLKIT

Web site(s):

http://www.cs.bham.ac.uk/~axs/cog_affect/sim_agent.html

Description from web site:

The SimAgent toolkit (originally called SIM_AGENT) provides a range of resources for research and teaching related to the development of interacting agents in environments of various degrees and kinds of complexity. It can be run as a pure simulation tool, or installed in a robot with a sufficiently powerful on-board computer, e.g. running linux. It was originally developed to support exploratory research on human-like intelligent agents, but has also been used for student projects developing a variety of interactive games and simulations. Unlike many so-called 'agent toolkits', like PRS/Jack, Mozart, Alice, and several more, that are aimed mainly at development of systems involving large numbers of highly distributed fairly homogeneous relatively 'small' agents, SimAgent can be used for such purposes (and is being used e.g. by Matthias Scheutz at Notre Dame University) but (like ACT-R, COGENT, and the original SOAR) is primarily designed to support design and implementation of very complex agents, each composed of very different interacting components (like a human mind) where the whole thing is embedded in an environment that could be a mixture of physical objects and other agents of many sorts.

Tool: Simulation of Cognitive Agents

Web site(s):

http://www.lti.pcs.usp.br/SimCog/

Description from web site:

SIMCOG (Simulation of Cognitive Agents) is a research project that aims to develop a generic platform for multi-agent based simulation of cognitive agents. It has started in 2001 at the Dept. of Informatics, University of Lisbon, and at the Intelligent Techniques Laboratory, University of São Paulo. The project has two independent and cross-fertilizable phases. The first one is to define a reference model for the requirements specification of an ideal type agent-based simulation platform. In this phase we adopt two independent approaches: (i) we make a comparative analysis between different platforms that are presently available to the research community; (ii) we prospect and explore requirements with researchers in the field. The second phase is the specification, design and implementation of an agent-based simulation platform complying with a subset of these requirements, with special focus on the simulation of cognitive agents. To this end we have specified a multi-agent meta-model according to an organisation-centered approach, in order to simulate multi-agent societies. The meta-model is called MOSCA (Meta Organisation for Simulation of Cognitive Agents). The term "meta" is used because the SimCog platform infrastructure is based on a MAS, which constructs and controls the simulated MAS. MOSCA is guided by the following general principles: Provide an infrastructure to observe and intervene on both behavioural and cognitive events in a simulation. In order to observe possible emergent structures playing causal roles in the simulation, we formally separate the observation of the agent's behavioural (external) and cognitve (internal) events. This can be done at the individual or aggregate levels. Provide ontologies for knowledge sharing, reuse, simulation modelling and interoperability of simulations.

Tool: StarLogo

Sources:

Starlogo for the PC Home Page at MIT includes examples and tutorials, etc. *http://www.media.mit.edu/starlogo/*

Starlogo for the Macintosh Home Page at MIT *http://www.media.mit.edu/macstarlogo/index.html*

An introductory book covering designing, creating and investigating models using StarLogo: 'Adventures in Modeling' Vanessa Stevens Colella, Eric Klopfer, Mitchel Resnick. ISBN: 0807740829 *http://www.media.mit.edu/starlogo/adventures/*

Connected Mathematics Team at Northwestern University contains lots of models implemented in StarlogoT (for the Macintosh) and a useful list of links. *http://www.ccl.sesp.northwestern.edu/cm/*

Starlogo sites at Maine University. *http://www.asap.um.maine.edu/starlogo/*

The simulation of the Spread of Malaria in Haiti developed at GRIC IRIT by Fatima Rateb, Narges Bellamin and Bernard Pavard. *Click here* to see the simulation running.

Web site(s):

http://education.mit.edu/starlogo/

Description from web site:

StarLogo is a programmable modeling environment for exploring the workings of decentralized systems -- systems that are organized without an organizer, coordinated without a coordinator. With StarLogo, you can model (and gain insights into) many real-life phenomena, such as bird flocks, traffic jams, ant colonies, and market economies. In decentralized systems, orderly patterns can arise without centralized control. Increasingly, researchers are choosing decentralized models for the organizations and technologies that they construct in the world, and for the theories that they construct about the world. But many people continue to resist these ideas, assuming centralized control where none exists -- for example, assuming (incorrectly) that bird flocks have leaders. StarLogo is designed to help students (as well as researchers) develop new ways of thinking about and understanding decentralized systems. StarLogo is a specialized version of the Logo programming language. With traditional versions of Logo, you can create drawings and animations by giving commands to graphic "turtles" on the computer screen. StarLogo extends this idea by allowing you to control thousands of graphic turtles in parallel. In addition, StarLogo makes the turtles' world computationally active: you can write programs for thousands of "patches" that make up the turtles' environment. Turtles and patches can interact with one another -- for example, you can program the turtles to "sniff" around the world, and change their behaviors based on what they sense in the patches below. StarLogo is particularly well-suited for Artificial Life projects.

Comment from Julie Dugdale (http://www.irit.fr/COSI/training/evaluationoftools/Evaluation-Of-Simulation-Tools.htm):

A programmable modelling environment specifically aimed towards exploring decentralised systems via simulation. Starlogo is a specilaized version of logo (which was used for teaching in schools). Starlogo allows the user to create and control the behaviour of 'turtles' (a term kept over from Logo days). Turtles move around a user-defined landscape that is make up of 'patches'. Whilst Starlogo can be considered 'agent-based' (for example, a turtle is an agent) its programming paradigm is procedural (as opposed to object-oriented for example). What does this mean in practice? Very broadly, there are several main programming paradigms (for example: procedural, object-oriented, declarative, etc.). A programming language may be categorized into one of the paradigms. One way to categorize a language is the 'style' of programming that it adopts. Thus, Pascal, Modula2, and basic are procedural languages; C++, Java and SmallTalk are object-oriented and Prolog is declarative. There are many differences between the different paradigms, but the main point for this paper is that if a person has experience with one particular programming paradigm, he or she will have to learn a new way of thinking about the problem to be able to model and code using another paradigm. So, back to Starlogo! Starlogo is procedural. It provides a set of commands which the programmer uses to create and control the turtles & patches. In practice, Starlogo is very easy to use (even for those people who have very little experience of programming). Starlogo provides a graphical interface to help the developer code their simulations. It is very easy to create graphs of simulation data and to define buttons and slide bars which control the simulation and define the input data (e.g. number of turtles). However, whilst it is very easy to graph data in Starlogo there are some annoying problems associated with the graphing facility (for example, whilst many lines may be plotted on the same graph, it is not possible create more than one graph). With the current version of Starlogo (ver. 1.2), it is quite easy to put your simulations in a web page as an applet for viewing. Starlogo is available for the Mac or PC. However, simulations which are developed and run on one platform will NOT run on the other. Thus if a colleague has a Starlogo simulation running on a Mac, you won't be able to run it on your PC. There are a lot of examples of Starlogo simulations available on the internet and there is a very good support mailing help group. One of the main downfalls of Starlogo (particularly if we are addressing social science problems) is its inflexibility. The set of commands offered by Starlogo may be quite restrictive if we are aiming to code complex social mechanisms. It is not impossible to code such things in Starlogo, but it may be quite frustrating and challenging to find ways to do exactly what you want given the commands provided. In addition, whilst it is unnecessary to have a lot of programming experience, care must be taken to avoid writing inefficient code which can make your simulations frustratingly slow.

Tool: SWARM

Sources:

The Swarm Development Group contains tutorials, examples, community projects and code. http://www.swarm.org/

Paul Johnson's Swarm User Guide http://lark.cc.ukans.edu/~pauljohn/Swarm/Beta/SwarmUserGuide/userbook.html

Paul Johnson's Swarm HQ includes lots of examples of Swarm code http://lark.cc.ukans.edu/~pauljohn/Swarm/

Louis Foucart's article: 'A Small Multi Agent Systems Review' which covers Swarm *http://geneura.ugr.es/~louis/masReview.html*

Web site(s):

http://www.swarm.org/wiki/Main_Page

Description from web site:

Swarm is a platform for agent-based models (ABMs) that includes: A conceptual framework for designing, describing, and conducting experiments on ABMs; Software implementing that framework and providing many handy tools; and a community of users and developers that share ideas, software, and experience. Swarm materials are organized in three categories, each with its own main page on this wiki: Software, Documentation and learning materials, and example applications and contributed code.

Comment from Julie Dugdale (http://www.irit.fr/COSI/training/evaluationoftools/Evaluation-Of-Simulation-Tools.htm):

Swarm was originally developed by the Santa Fe Institute specifically for multi-agent simulation of complex adaptive systems. Until recently the Swarm project was based at the Santa Fe Institute but its development and management is now under control of the Swarm Development Group. Swarm provides a set of libraries which the developer uses for building models and analysing, displaying and controlling experiments on those models. The libraries are written in Objective C and until recently building a simulator meant programming in a mixture of Objective C and Swarm. However, it is now possible to use Java (and again some Swarm) to call upon the facilities offered by the libraries. The Java 'extension' is particularly useful since Java is a very common and powerful language. The next release of Swarm, will support JavaScript and Scheme in addition to Objective C and Java. In the Swarm system, the fundamental component that organises the agents of a Swarm model is a 'swarm'. A swarm is a collection of agents with a schedule of events over those agents. The swarm represents an entire model: it contains the agents as well as the representation of time. Swarm supports hierarchical modelling whereby an agent can be composed of swarms of other agents in nested structures. In this case, the higher level agent's behaviour is defined by the emergent phenomena of the agents inside its swarm. This multi-level model approach offered by Swarm is very powerful. Multiple swarms can be used to model agents that themselves build models of their world. In Swarm, agents can themselves own swarms, models that an agent builds for itself to understand its own world. The actual model and the task of observing the model is clearly separated in the Swarm system. In Swarm, there are special 'observer' agents whose purpose it is to observe other objects via the probe interface. These objects can provide both real-time data presentation and storage of data for later analysis. The observer agents are actually swarms (a group of agents and a schedule of activity) and combining the observer swarm with the model swarm gives a complete experimental framework (model and observer apparatus). With other simulation tools the distinction between the actual model and the code needed to observe and collect data from the model is blurred making it difficult to change one part without influencing the other. Separating the model from the rubric of its observation means that the model itself can remain pure and unchanged if the observation code needs to be modified. Swarm is probably the most powerful and flexible simulation platform. However, this comes at a price. In practice, Swarm has a very steep learning curve. It is

necessary to have experience of Java (or Objective C), be acquainted with the object-oriented methodology and be able to learn some Swarm code. In terms of additional support, there are excellent support mailing lists (with prompt and helpful responses) and a lot of generally available Swarm/Java/Objective C code. There is also an annual meeting of the Swarm Users Group called SwamFest where researchers from diverse disciplines present their experience with multi-agent modeling and the Swarm simulation system. Immediately preceeding SwarmFest there is usually a tutorial for inexperienced users on how to use Swarm. Swarm models can already run inside a web browser, specifically Netscape 6. However, a future development goal is for Swarm to be a complete interactive, browser-based development environment for agent-based models. Swarm runs on any platform. With reference to building simulations for the social sciences: Swarm would be one of the best platforms to use, being so powerful and flexible that it would be possible to implement very intricate and complicated social mechanisms. The only pre-requisite would be finding a programmer experienced enough to be able to implement what was needed.

9.3.5 Simulation Tools

Tool: Arena

Sources:

Rockwell Automation

Web site(s):

http://www.arenasimulation.com/

Description from (http://www.idsia.ch/~andrea/simtools.html):

The home of ARENA which has an object-oriented design and the ability to be tailored to any application area. Is based on SIMAN modelling language.

Tool: AutoMod

Sources:

Brooks Automation

Web site(s):

http://www.automod.com/index.html

Description from (http://www.idsia.ch/~andrea/simtools.html):

AutoMod suite provides simulation software that gives a 3D visual image of a facility as well as statistics of how the facility will perform.

Tool: BuildSim

Sources:

Tritera

Web site(s):

http://www.tritera.com/products/web_buildsim/bs_page1.shtml

Description from (http://www.idsia.ch/~andrea/simtools.html):

BuildSim, by Tritera, is an Integrated Environment for Design, Simulation and Analysis of Systems. BuildSim is an interactive software application that integrates numerical analysis, block diagram mathematical representations, signal processing and graphics in a graphical interactive environment. It allows to generate source-code (C++ and Java). Available for Macintosh. There is a version available for download.

Tool: DESIRE

Sources:

DESIRE/2000

Web site(s):

http://members.aol.com/gatmkorn/

Description from (http://www.idsia.ch/~andrea/simtools.html):

DESIRE (Direct Executing SImulation in REal Time) is a very fast interactive modeling and simulation of dynamic systems, used in industry and education since 1986. Runtime compilation lets your programs execute without translation delays. This permits truly interactive modeling and immediate comparisons of live models. An academic version that allows to handle aÊsix state system can be downloaded for free. DESIRE/2000 for Windows includes an experiment-protocol language for controlling multirun simulation studies, and an industrial-strength differential-equation solver. DESIRE/2000 handles up to 20,000 first-order differential equations entered in readable scalar or matrix notation, with a choice of 14 integration rules. Multiple models can include user-designed neural networks and fuzzy logic.

Tool: Extend Suite

Sources:

Imagine That, Inc.

Web site(s):

http://www.imaginethatinc.com/

Description from (http://www.idsia.ch/~andrea/simtools.html):

Extend is a simulation environment used to model, analyze, and optimize processes. It has a lot of features like libraries of components, hierarchies of models, linking with MS Office, and the ability to model continuous, discrete event, and hybrid systems. Extend has its own modeling language (ModL) which resembles C, and the ability to call code from other languages. It has specialized packages for Industrial Systems, Operations Research, and Continuous Process simulations.

Tool: GoldSim

Sources:

GoldSim

Web site(s):

http://www.goldsim.com/

Description from (http://www.idsia.ch/~andrea/simtools.html):

GoldSim is a general purpose simulator for nearly any kind of physical, financial or organizational system. Models are built graphically drawing an influence diagram of your system. Goldsim Academic is offered free for students, professors and teachers. Goldsim also provides a player that enables anyone to view your model, without requiring the installation of the full package. Goldsim also provides dedicated modules for specific issues such as contaminant transport, radionuclide decay. Goldsim simulation can also be run in a distributed environment thanks to the Godlsim DP component.

Tool: Micro Saint

Sources:

Micro Analysis and Design

Web site(s):

http://www.maad.com/index.pl/micro_saint

Description from (http://www.idsia.ch/~andrea/simtools.html):

Micro Saint is a general purpose, flexible simulation software product. It has a graphical user interface and is based on a flow chart approach to modeling. Runs on Windows machines. Demo available for download.

Tool: NCTUns 2.0

Sources:

SimReal Inc.

Web site(s):

http://nsl.csie.nctu.edu.tw/nctuns.html

Description from (http://www.idsia.ch/~andrea/simtools.html):

The NCTUns is a high-fidelity and extensible network simulator and emulator capable of simulating various protocols used in both wired and wireless IP networks. Its core technology is based on the novel kernel re-entering methodology. NCTUns can be used as an emulator, it directly uses the Linux TCP/IP protocol stack to generate high-fidelity simulation results, and it has many other interesting qualities.

Tool: OPNET

Sources:

OpNet

Web site(s):

http://www.opnet.com/

Description from (http://www.idsia.ch/~andrea/simtools.html):

OPNET's suite of products combine predictive modeling and a comprehensive understanding of networking technologies to enable customers to design, deploy, and manage network infrastructure, network equipment, and networked applications. In particular OPNET Modeler is a development environment, allowing you to design and study communication networks,devices, protocols, and applications.

Tool: ProModel

Sources:

ProModel VAO Technology

Web site(s):

http://www.promodel.com/

Description from (http://www.idsia.ch/~andrea/simtools.html):

ProModel Optimization Suite is a simulation-based software tool for evaluating, planning or re-designing manufacturing, warehousing and logistics systems.

Tool: SimCad Pro

Sources:

Create A Soft

Web site(s):

http://www.createasoft.com/

Description from (http://www.idsia.ch/~andrea/simtools.html):

SimCAD Pro is a Process Simulation and modeling tool, which allows top down modelling of complex industrial processes. The main process flow is defined and then each process cell is expanded into its individual processes. CreateAsoft, the maker of SimCad pro, also provides a viewer to show and distribute your simulations.

Tool: SimCreator

Sources:

RealTime Technologies inc

Web site(s):

http://www.simcreator.com/

Description from (http://www.idsia.ch/~andrea/simtools.html):

SimCreator is a graphical simulation and modeling system. It is aimed at the simulation of continuous time systems. It's interface is similar to Mathworks's Simulink. Simpler models can be connected to build complex models. Models can be nested. The graphical specification is then translated in C code. A beta version is avaliable for download , while a commercial version is expected for the 4th quarter of 2000.

Tool: SIMUL8

Sources:

Visual Thinking Intl.

Web site(s):

http://www.simul8.com/

Description from (http://www.idsia.ch/~andrea/simtools.html):

SIMUL8 by Visual Thinking Intl. It allows the user to pick from a predefined set of simulation objects and statistical distributions to create the model. It also allows hierarchical modelling. Main focus on discrete event simulation.

Tool: SimProcess and SimScript

Sources:

CACI Products Company

Web site(s):

http://www.simprocess.com/default.html

Description from (http://www.idsia.ch/~andrea/simtools.html):

Simprocess is an object-oriented, process modeling and analysis tool. It combines the simplicity of flowcharting with the power of simulation, statistical analysis, Activity-Based Costing (ABC), and animation.

Tool: Symbols 2000

Sources:

Symbols 2000

Web site(s):

http://www.symbols2000.com/

Description from (http://www.idsia.ch/~andrea/simtools.html):

Symbols 2000, a product of two decades of research at the Indian Institute of Technology of Kharagpur, is a graphical modeling, simulation and control software. It provides an object oriented modeling tool using bond graphs, block diagrams, and equation models to model dynamic systems. Online simulation with event handlers. Pre-cast sub-models for advanced engineering components. Full C++ compatibilty. Analog, digital and state-space analysis using control systems module. Demos for DOS and NT are available.

Tool: VisSim

Sources:

Visual Solutions

Web site(s):

http://www.vissim.com/

Description from (http://www.idsia.ch/~andrea/simtools.html):

VisSim, a visual block diagram language for nonlinear dynamic simulation. A block API allows users to create their own blocks in C/C++, FORTRAN, ADA, or Pascal. Addons allow real-time analog and digital I/O for real-time simulation, embedded system C code generation, optimization, neural nets, OPC, frequency domain analysis, scaled fixed point, IIR and FIR filter design. Demo available for download from the home page.

Tool: Visual Components

Sources:

Visual Components

Web site(s):

http://www.visualcomponents.com/portal/products

Description from (http://www.idsia.ch/~andrea/simtools.html):

Visual Components provides tools to package complex automation systems into re-useable simulation components that are lightweight, easily customized and distributed via email. The re-useable visual components save automation companies costs in all phases of a system's life-cycle. These components implement COM interfaces and run in a Windows environment. The components are also scriptable using the Python language.

Tool: WITNESS

Sources:

Lanner

Web site(s):

http://www.lanner.com/home/the_value_of_knowing.php

Description from (http://www.idsia.ch/~andrea/simtools.html):

WITNESS, by Lanner Group, provides a graphical environment to design discrete event simulation models. It allows to automate simulation experiments, optimize material flow across the facility, and generate animated 3D virtual reality models.

10 Conclusion

A number of 471 references have been identified, studied and classified in this document. An additional number of 713 potential web site addresses were added for further searches. Table 2 shows a summary of their distribution in function of Chapters and Sections.

Table 2 Summary on References Included in this Document.

Chapter & Section Number	Chapter & Section Title	Nbr of Sci. Docs	Nbr of Books	Nbr of Web Refs
2.1	General Theory of System		1	
2.2	Systems Thinking	5	5	
3.1	Related State-of-the-Arts	5		
3.2	Complexity Theory	13	21	
3.3	Complex Adaptive Systems	2	2	
3.4	Some Features and Characteristics of Complex Adaptive Systems	38	3	
3.5	Metrics for Complex Adaptive Systems	7		1
3.6	Sources of Complexity	1		
3.7	Perception and Comprehension of Complexity	3		
3.8	Managing Complexity and Complex Adaptive Systems	1		
3.9	Connectivity and Communication in Complex Adaptive Systems	2		
3.10	Aspects of Complexity and Chaos in Various Fields or Domains	79	30	4
4.0	Experts			25
5.0	Organizations			64
6.0	Projects			10
7.0	Journals			40
8.0	Conferences, Workshops			33
9.0	Tools for Complexity Science	1		
9.1	Frameworks	2		11
9.2	Other Methodologies, Approaches and Theories	7	4	1
9.3	Abstraction Languages and Tools			49
Annex B	Other Potential Web Site Addresses			713
	Total	**166**	**66**	**951**

Table 2 shows that the emphasis has been put on Sections 3.2, 3.4, 3.10 and on Chapters 4, 5, 6, 7 and 8. This insures the covering of the Complexity Theory, complex systems and implications of related concepts in various disciplines. The document also provides a sufficient level of information regarding experts, organizations, projects, journals and conferences. This should ease and accelerate the search of specific information and experts.

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A.4 Web Sites

Buenos Aires University's Center of Advanced Studies, 2006: http://www.cea.uba.ar/

Canergie Mellon Software Engineering Institute (SEI), 2006: http://www.sei.cmu.edu/

CCRP Publications Series, 2006: http://www.dodccrp.org/

Complexity International, 2006: http://www.complexity.org.au/

Euro-control Experimental Center, 2006: http://www.eurocontrol.int/

IDEF, 2006: Integrated Definition Methods, http://www.idef.com/

Massachusetts Institute of Technology (MIT), 2006: http://web.mit.edu/

NATO: http://www.nato.int/

New England Complex Systems Institute (NECSI), 2006: http://necsi.org/

Open Network of Centers of Excellence in Complex Systems (Once-cs), 2006: http://complexsystems.lri.fr/Portal/

System of Systems Engineering Center of Excellence, 2006: http://www.sosece.org

CALRESCO, 2006: Newsgroup: comp.theory.self-org-sys,

http://www.calresco.org/sos/sosfaq.htm

Wikipedia, 2006: http://en.wikipedia.org/wiki/

Annex B Other Potential Web Sites Addresses

This Annex contains a number of additional web site addresses obtained from search engines such as Google. They could not be studied in this work for time consideration. They have been included anyway in this document as potential references to help reader continue his/her searches.

B.1 General

http://csdl2.computer.org/comp/proceedings/icac/2005/2276/00/22760389.pdf

http://www.cscs.umich.edu/education/websites.html#simulationSystems

B.2 Agent, Multi-agent

http://cscs.umich.edu/~crshalizi/notebooks/agent-based-modeling.html

http://cscs.umich.edu/~crshalizi/notebooks/multi-agent-systems.html

http://homepages.inf.ed.ac.uk/mrovatso/talks/rovatsos-aaaisymp2002-talk.pdf

http://portal.acm.org/citation.cfm?id=544741.544849&coll=GUIDE&dl=GUIDE&type=series&idx=544741&part=Proceedings&WantType=Proceedings&title=International%20Conference%20on%20Autonomous%20Agents&CFID=69598135&CFTOKEN=90890622

http://portal.acm.org/citation.cfm?id=646910.710814

http://www.aaai.org/Press/Reports/Symposia/Spring/ss-02-02.php

http://www.aamas2004.org/proceedings/267_SauvageS_Patterns.pdf

http://www.agentgroup.unimo.it/aose05/

http://www.aiai.ed.ac.uk/project/ix/documents/2004/2004-aaai-isd-tate-cosarts.pdf

http://www.cs.mu.oz.au/~tlj/p512-juan.pdf

http://www.cs.ualberta.ca/~bowling/papers/00tr.pdf

http://www.cs.utexas.edu/~pstone/Workshops/2002aaai/

http://www.csc.liv.ac.uk/~mjw/aose/

http://www.inderscience.com/browse/index.php?journalCODE=ijaose

http://www.modelingcomplexity.org/workshop2004/

http://www.nsi.edu/users/seth/Papers/sab02b.pdf

http://www.sce.carleton.ca/netmanage/docs/AgentsOverview/ao.html

http://www.sei.cmu.edu/isis/references/technology/agent-space.pdf

B.3 Air Traffic Management

http://web.mit.edu/16.459/www/Pawlak.pdf

http://web.mit.edu/aeroastro/www/labs/halab/papers/CummingsTsonisISAP.pdf

http://web.mit.edu/esd.83/www/notebook/ESD83-Airlines.doc

http://web.mit.edu/esd.83/www/notebook/Transportation%20-%20Airline%20Ind.ppt#256,1,Systems in Transportation: the case of the airline industry

http://www.demarcken.org/carl/papers/ITA-software-travel-complexity/img0.html

B.4 Artificial Life

http://alf.nbi.dk/~emmeche/cePubl/92c.modlif.html

http://alf.nbi.dk/~emmeche/Welcome.html

http://alife.fusebox.com/

http://alife6.alife.org/

http://archive.comlab.ox.ac.uk/comp/ai.html

http://cscs.umich.edu/~crshalizi/notebooks/ai.html

http://cscs.umich.edu/~crshalizi/notebooks/alife.html

http://dmoz.org/Computers/Artificial_Life/

http://geocities.com/goldenziby/alife.html

http://homepages.feis.herts.ac.uk/~comqkd/Alife.htm

http://lachlan.bluehaze.com.au/alife.html

http://mitpress.mit.edu/catalog/item/default.asp?ttype=2&tid=3979

http://neuron-ai.tuke.sk/~ulicny/allives.htm

http://staff.aist.go.jp/utsugi-a/Lab/Links.html

http://www.acm.org/acm97/conference/laurel_maes.html

http://www.alcyone.com/max/links/alife.html

http://www.alife.net/

http://www.aridolan.com/

http://www.aridolan.com/ad/adb/adib.html

http://www.aridolan.com/ad/admain.html

http://www.aridolan.com/ofiles/JavaFloys.html

http://www.artificial-life.com/

http://www.bbc.co.uk/education/darwin/

http://www.channon.net/alastair/

http://www.cs.brandeis.edu/~zippy/alife.html

http://www.cs.brandeis.edu/~zippy/alife-groups.html

http://www.cs.brandeis.edu/~zippy/alife-journals.html

http://www.cs.brandeis.edu/~zippy/alife-library.html

http://www.cs.brandeis.edu/~zippy/alife-people.html

http://www.cs.cmu.edu/afs/cs/project/ai-repository/ai/areas/alife/systems/life/hatch/0.html

http://www.cs.cmu.edu/afs/cs/project/ai-repository/ai/areas/alife/systems/life/0.html

http://www.cs.cmu.edu/afs/cs/user/phoebe/mosaic/work/artificial-life.html

http://www.cs.ucl.ac.uk/staff/t.quick/alife.html

http://www.csail.mit.edu/index.php

http://www.econ.iastate.edu/tesfatsi/alsched.f97.htm

http://www.euronet.nl/users/ragman/link_64.html

http://www.faqs.org/faqs/ai-faq/alife/

http://www.faqs.org/faqs/by-newsgroup/comp/comp.ai.alife.html

http://www.geocities.com/ResearchTriangle/1402/

http://www.gustavus.edu/oncampus/academics//philosophy/lalife.html

http://www.gypsymoth.ento.vt.edu/~sharov/biosem/biosem.html

http://www.informatics.indiana.edu/fil/

http://www.informatics.susx.ac.uk/easy/index.html

http://www.insead.fr/CALT/Encyclopedia/ComputerSciences/AI/aLife.htm

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http://www.krl.caltech.edu/avida/home/links.html

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http://www.lalena.com/ai/

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http://www.mitpressjournals.org/loi/artl

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http://www.rennard.org/alife/

http://www.santafe.edu/~hag/

http://www.univie.ac.at/constructivism/people/riegler/

http://www.well.com/user/xanthian/link_pages/Programming/Paradigms/ArtificialLife.html

http://www-cgi.cs.cmu.edu/afs/cs.cmu.edu/project/ai-repository/ai/areas/alife/systems/psoup/0.html

http://www-cgi.cs.cmu.edu/afs/cs/project/ai-repository/ai/areas/alife/0.html

http://www-cse.ucsd.edu/users/rik/subsection3_3_3.html

http://www-users.cs.york.ac.uk/~susan/complex/index.htm

B.5 Aspects Oriented Programming

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B.36 Neural Network

http://www.cogs.susx.ac.uk/users/ezequiel/alife-page/complexity.html

B.37 Neurocomputing

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B.38 Nonlinear Dynamics

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B.52 Systems Engineering, Architecting, Methodologies, Project Management

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B.54 Visualization

http://www.visualcomplexity.com/vc/

B.55 Additional Web Site Addresses

comp.ai - artificial intelligence

comp.ai.alife - artificial life

comp.ai.genetic - genetic algorithms and evolutionary computation

comp.ai.neural-nets - neural networks

comp.robotics - robotics

comp.theory.cell-automata - cellular automata

comp.theory.dynamic-sys - dynamic systems

comp.theory.self-org-sys - self organizing systems & sponsor of this FAQ

http://165.227.26.1/et/self.html - Self-organizing concepts & tools

http://algodones.unm.edu/~bmilne/bio576/instr/html/SOS/sos.html - introduction

http://armyant.ee.vt.edu/unsalWWW/cemsthesis.html - Self-Organisation in Large Populations of Mobile Robots

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http://bactra.org/Self-organization/soup-done/ - Is the Primordial Soup Done Yet ?

http://ciiiweb.ijs.si/dialogues/r-detela.htm - Self-Organization within Complex Quantum States

http://dllab.caltech.edu/avida/ - Avida (The Digital Life Laboratory)

http://dsp.jpl.nasa.gov/members/payman/swarm/ - swarm intelligence resources

http://foto.hut.fi/~markus/selforg.html - extensive links to SOS online papers/sites

http://goertzel.org/dynapsyc/1996/fred.html - Chaos, Bifurcations & Self-Organization: Dynamical Extensions of Neurological Positivism & Ecological Psychology

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http://necsi.org/ - New England Complex Systems Institute

http://newton.uor.edu/FacultyFolder/JSpee/iaf99/Thread1/conway.html - Conditions That Support Self-Organization in A Complex Adaptive System

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http://pil.phys.uniroma1.it/eec1.html - Fractal Structures and Self-Organization

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http://platon.ee.duth.gr/~soeist7t/paper//kueppers2.html - Coping with Uncertainty: The Self-Organisation of Social Systems

http://tornade.ere.umontreal.ca/~philippp/Back_to_basics - Complex Systems Theory

http://views.vcu.edu/complex - VCU complexity research group

http://websom.hut.fi/websom/ - WEBSOM Self-Organizing Maps

http://www.acm.org/sigois/auto/Main.html - Self-Org, Autopoiesis & Enterprises

http://www.alcyone.com/max/links/alife - Artificial Life links

http://www.astro.cf.ac.uk/pub/Jos.Thijssen/sandexpl.html - Java sandpile

http://www.brint.com/Systems.html - Complex Systems & Chaos Theory

http://www.c3.lanl.gov/~rocha/ises.html - Selected Self-Organization

http://www.calresco.org/ - CALResCo, home of this FAQ, introductions, essays & resources

http://www.ccs.fau.edu - The Center for Complex Systems

http://www.cis.hut.fi/~sami/thesis/thesis_tohtml.html - Data Exploration Using Self-Organizing Maps

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http://www.democracynature.org/dn/vol6/best_kellner_kelly.htm - Kevin Kelly's Complexity Theory: The Politics & Ideology of Self-Organizing Systems

http://www.dimacs.rutgers.edu/Projects/Simulations/darpa/ - Scalable Self-Organizing Simulations

http://www.evalife.dk/cycliophora/cycliophora.html - EVALife: Self-organisation in life-cycles

http://www.ezone.com/sos - SOS on the Web

http://www.fes.uwaterloo.ca/u/jjkay/pubs/thesis/toc.html - Self-Organization In Living Systems

http://www.fes.uwaterloo.ca/u/mbldemps/pubs/mesthe/ - A Self-Organizing Systems Perspective on Planning For Sustainability

http://www.fmb.mmu.ac.uk/~bruce/evolcomp - What is complexity ?

http://www.geo.uni-bonn.de/members/hergarten/self-organ.html - Self-organization and fractals

http://www.iephb.ru/spirov.html - self-organisation in biology

http://www.ifs.tuwien.ac.at/ifs/research/pub_html/rau_wirn98/wirn98.html - Distributed Digital Library based on Self-Organizing Maps

http://www.labs.bt.com/projects/ibsr/dynamo.htm - Self-Organising Adaptive Systems

http://www.physics.uiuc.edu/groups/complex.html - Complex & Nonlinear science

http://www.prototista.org/ - ProtoTista complexity education

http://www.qedcorp.com/pcr/pcr/Kauffman.htm - Of Flesh and Ghosts: Self-Organization as Post-Quantum Physics

http://www.qedcorp.com/pcr/pcr/Kauffman.htm - Self-Organization as Post-Quantum Physics

http://www.radix.net/~ash2jam/holarchy.htm - Holarchies: The Metapattern of the Self-Organizing Universe

http://www.radix.net/~crbnblu/assoc/oconnor/chapt1.htm - Systems Thinking

http://www.red3d.com/cwr/boids/ - Craig Reynold's Boids, artificial birds

http://www.rwcp.or.jp/people/yk/CCM/HICSS27/paper/CCM-ProblemSolving.html - Stochastic problem solving by SO

http://www.sandia.gov/media/atomorg.htm - Self-Organising Nanopatterns

http://www.santafe.edu/ - Santa Fe Institute

http://www.santafe.edu/~wuensch/thesis.html - Attractor Basins of Discrete Networks: Implications on self-organisation and memory

http://www.santafe.edu/sfi/publications/Bulletins/bulletin-spr95/12debate.html

http://www.serve.com/~ale/html/cplxsys.html - Complex Adaptive Systems

http://www.stigmergicsystems.com/ - stigmergic systems

http://www.tec.spcomm.uiuc.edu/nosh/icasost/nc.html - Self-Organizing Systems Research in the Social Sciences:

http://www.trincoll.edu/depts/psyc/homeokinetics/ - Homeokinekics

http://www.weiterbildung.unizh.ch/texte/soisoc.shtml - The Self-Organizing Information Society

http://www.wolfram.com/s.wolfram/articles/82-cellular/index.html - CAs as SOS

http://xxx.lanl.gov/archive/adap-org/ - Archive of Adapation/SOS papers

sci.bio.evolution - natural organization and evolution

sci.fractals - fractal and self-similar systems

sci.nonlinear - nonlinear and chaotic systems

sci.systems - systems

Annex C List of Searched Databases

Table 3 List of Searched Databases (Dialog Database Catalog, 2005).

INSPEC
NTIS
EI Compendex
Sci Search (1990+)
Science
Inside Conferences
Japanese Science & Technology (JICST)
Technology and Management (TEME)
Wilson Applied Science and Technology Abstracts
Pascal
Federal Research in Progress (FEDRIP)
PEDS: Defense Program Summaries
JANE'S Defense & Aerospace News/Analysis
Gale Group Aerospace/Defense Market & Technology
Techinfo Source
Math Sci
ERIC

SPIN

Annex D Santa Fe Institute (SFI) Publications

Some of the references included in this Annex are already included in the Reference Section of this document. Considering the importance of SFI for complex sciences, most scientific documents from this institute and associated Professors have been grouped in this Annex.

D.1 Scientific Papers

The reader is invited to refer to the following web site for a complete list of scientific papers.

http://www.santafe.edu/research/publications/working-papers.php

D.2 Books

http://www.santafe.edu/research/publications/alphalist.php

- Adaptive Individuals in Evolving Populations: Models and Algorithms, Edited by R. K. Belew and M. Mitchell, ISBN: 0-201-48369-6
- Artificial Life, Edited by C. G. Langton , ISBN: 0-201-09356-1
- Artificial Life II, Edited by C. G. Langton, C. Taylor, J. D. Farmer, and S. Rasmussen *Also Artificial Life II Video Proceedings*
- Artificial Life III, Edited by C. G. Langton, ISBN: 0-201-62494-X
- Auditory Display: The Proceedings of ICAD '92, the International Conference on Auditory, Display, Edited by Gregory Kramer, ISBN: 0-201-62604-7
- Complex Systems Dynamics, By G. Weisbuch, ISBN: 0-201-62732-9
- Complexity, Entropy, and the Physics of Information, Edited by W. H. Zurek
- Complexity: Metaphors, Models, and Reality, Edited by George A. Cowan, David Pines, and David Meltzer, ISBN: 0-201-62606-3
- Computers and DNA, Edited by G. I. Bell and T. G. Marr
- Design Principles for the Immune Systems and Other Distributed Autonomous Systems, Edited by Irun Cohen and Lee Segel, ISBN: 0195136993
- The Double Auction Market: Institutions, Theories, and Evidence, Edited by D. Friedman and J. Rust, ISBN: 0-201-62263-7
- Evolutionary Dynamics: Exploring the Interplay of Selection, Accident, Neutrality, and Function, Edited by James P. Crutchfield and Peter Schuster, ISBN: Cloth 0195142640, Paper 0195142659
- Dynamics in Human and Primate Societies: Agent-Based Modeling of Social and Spatial Processes, Edited by Timothy A. Kohler and George J. Gumerman, ISBN: Cloth 0-19-513167-3, Paper 0-19-513168-1

- The Economy as an Evolving Complex System, Edited by P. W. Anderson, K. Arrow, and D. Pines, ISBN: 0-201-15685-7
- The Economy as an Evolving Complex System II, Edited by W. B. Arthur, S. N. Durlauf, and D. Lane, ISBN: 0-201-32823-2
- Emerging Syntheses in Science, Edited by D. Pines, ISBN: 0-201-15686-5
- Evolution of Human Languages, Edited by J. A. Hawkins and M. Gell-Mann ISBN: 0-201-52572-0
- Evolving Complexity and Environmental Risk in the Prehistoric Southwest, Edited by Joseph A. Tainter and Bonnie Bagley Tainter, ISBN: 0-201-87040-1
- The Global Dynamics of Cellular Automata: An Atlas of Basin of Attraction Fields of One-Dimensional Cellular Automata, By A. Wuensche and M. J. Lesser
- Integrating Geographic Information Systems and Agent-Based Modeling Techniques for Understanding Social and Ecological Processes, Edited by Randy Gimblett, ISBN: 0195143361
- Introduction to the Theory of Neural Computation, By J. A. Hertz, A. S. Krogh, and R. G. Palmer
- Lattice Gas Methods for Partial Differential Equations, Edited by G. Doolen et al.
- Lectures in the Sciences of Complexity, Edited by D. Stein
- The Mathematics of Generalization, Edited by David H. Wolpert
- Maturational Windows and Adult Cortical Plasticity, Edited by B. Julesz and I. Kovacs
- The Mind, the Brain, and Complex Adaptive Systems, Edited by J. Singer and H. Morowitz
ISBN: 0-201-40988-7
- Modeling Extinction, By M. E. J. Newman and R. Palmer, ISBN: Cloth 0195159454, Paper 0195159462
- Molecular Evolution on Rugged Landscapes: Proteins, RNA, and the Immune System, Edited by A. S. Perelson and S. A. Kauffman
- 1989 Lectures in Complex Systems, Edited by E. Jen, ISBN: 0-201-50936-9
- 1990 Lectures in Complex Systems, Edited by L. Nadel and D. Stein
- 1991 Lectures in Complex Systems, Edited by L. Nadel and D. Stein
- 1992 Lectures in Complex Systems, Edited by L. Nadel and D. Stein
- 1993 Lectures in Complex Systems, Edited by L. Nadel and D. Stein ISBN: 0-201-48368-8
- New Constructions in Cellular Automata, Edited by David Griffeath and Cristopher Moore
ISBN: Cloth 0195137175, Paper 0195137183

- Nonextensive Entropy-Interdisciplinary Applications, Edited by Murray Gell-Mann and Constantino Tsallis, ISBN: Cloth 0195159764, Paper 0195159772
- Nonlinear Dynamics, Mathematical Biology, and Social Science, By Joshua M. Epstein ISBN: 0-201-41988-2
- Nonlinear Modeling and Forecasting, Edited by M. Casdagli and S. Eubank ISBN: 0-201-52764-2
- Pattern Formation in the Physical and Biological Sciences, Edited by H. F. Nijhout, L. Nadel, and D. L. Stein, ISBN: 0-201-40844-9
- The Principles of Organization in Organisms, Edited by J. E. Mittenthal and A. B. Baskin ISBN: 0-201-58789-0
- Reduction and Predictability of Natural Disasters, Edited by J. Rundle, B. Klein, and D. Turcotte, ISBN: 0-201-87049-5
- Robust Design: A Repertoire of Biological, Ecological, and Engineering Case Studies, Edited by Erica Jen, ISBN: Cloth 0195165322, Paper 0195165330
- Scaling in Biology, Edited by James Brown and Geoffrey West, ISBN: Cloth 0-19-513141-X, Paper 0-19-513142-8
- Spatio-Temporal Patterns in Nonequilibrium Complex Systems, Edited by P. Cladis and P. Palffy-Muhoray, ISBN: 0-201-40987-9
- Swarm Intelligence: From Natural to Artificial Systems, By Eric Bonabeau, Marco Dorigo, and Guy Theraulaz, ISBN: Cloth 0-19-513158-4, Paper 0-19-513159-2
- Theoretical Immunology (2 books: Part One and Part Two), Edited by A. S. Perelson
- Thinking About Biology, Edited by W. Stein and F. Varela, ISBN: 0-201-62454-0
- Time Series Prediction: Forecasting the Future and Understanding the Past, Edited by A. S. Weigend and N. A. Gershenfeld
- Viral Regulatory Structures and Their Degeneracy, Edited by Gerald Myers
- Understanding Complexity in the Prehistoric Southwest, Edited by G. Gumerman and M., Gell-Mann

D.3 Bulletins

The reader is invited to refer to the following web site for SFI Bulletins.

http://www.santafe.edu/research/publications/bulletin.php

D.4 Non-SFI Publications by Researchers Associated with SFI

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Annex E ERCIM (2006) Publications

Swarm-Based Space Exploration. Michael G. Hinchey, Roy Sterritt, Christopher A. Rouff, James L. Rash and Walt Truszkowski.

Collective Intelligence and Evolution. Akira Namatame, Akira Namatame, National Defense, Academy, Japan.

Evolving Game-Playing Strategies with Genetic Programming. Moshe Sipper, Ben-Gurion University, Israel.

Collaborative Online Development of Modular Intelligent Agents. Ciarán O'Leary, Dublin Institute of Technology, Mark Humphrys, and Ray Walshe, Dublin City University/IUA, Ireland.

CE-Ants: Ant-Like Agents for Path Management in the Next-Generation Internet Otto Wittner and Bjarne E. Helvik, NTNU, Norway.

ISEE – A Framework for the Evolution and Analysis of Recurrent Neural Networks for Embodied Agents. Martin Hülse, Steffen Wischmann, and Keyan Zahedi, Fraunhofer Institute for Autonomous Intelligent Systems – AIS, Fraunhofer ICT Group, Germany.

Emergent Intelligence in Competitive Multi-Agent Systems. Sander M. Bohte, Han La Poutré, CWI, The Netherlands.

Building a Computational Digital Economy through Interdisciplinary Research. Petros Kavassalis, University of Crete, Greece, and Konstantin Popov, Konstantin Popov SICS, Sweden.

Models of Multilateral Cooperative Behaviour. Milan Mareš Institute of Information Theory and Automation, Academy of Sciences / CRCIM, Czech Republic

Emergent Walking Behaviour in an Aibo Robot. Cecilio Angulo, Ricardo A. Téllez and Diego E. Pardo, Technical University of Catalonia (UPC) / SpaRCIM, Spain.

Concept-Based Text Representations for Categorization Problems. Magnus Sahlgren, SICS, Sweden.

A Framework for Efficient Statistical Modelling. Daniel Gillblad and Anders Holst, SICS, Sweden.

Rules, Inferences and Robust Approximation at Work. Antonín Dvořák, Vilém Novák, Viktor Pavliska, University of Ostrava, Czech Republic.

Particle Swarm Optimization for the Reconstruction of Permittivity Range Profiles from Microwave Measurements. Simone Genovesi and Emanuele Salerno, ISTI-CNR, Italy.

Building Blocks from Biology for the Design of Algorithms for the Management of Modern Dynamic Networks. Gianni A. Di Caro, Frederick Ducatelle, Luca Maria Gambardella, Andrea

Rizzoli Istituto Dalle Molle di Studi sull'Intelligenza Artificiale (IDSIA), Manno-Lugano, Switzerland.

Chemical Programming of Self-Organizing Systems. Jean-Pierre Banâtre, Pascal Fradet and Yann Radenac, INRIA/IRISA, France.

A Development Model for Robust Fault-Tolerant Design. Andy Tyrrell and Hong Sun, University of York, UK.

Emergent Properties of the Human Immune Response to HIV Infection: Results from Multi-Agent Computer Simulations. Ashley Callaghan, Dublin City University / IUA, Ireland.

Network Emergence in Immune System Shape. Heather Ruskin, and John Burns, Dublin City University, Ireland.

Agent-Based Modelling of Viral Infection. Dimitri Perrin, Dublin City University / IUA, Ireland.

The ‘Decent’ Project: Decentralized Metaheuristics. Enrique Alba, University of Málaga / SpaRCIM, Spain, and Martin Middendorf, University Leipzig, Germany.

Evolutionary Methods make New Effective Laser Shapes. Thomas Bäck and Joost N. Kok, Leiden University, The Netherlands.

Neural Net Modelling in Financial Engineering of Options. Jerome Healy, Longchuan Xu, Maurice Dixon, Fang Fang Cai, Brian Read and Brian Eales.

Self-Optimization in a Next-Generation Urban Traffic Control Environment. Raymond Cunningham, Jim Dowling, Anthony Harrington, Vinny Reynolds, René Meier and Vinny Cahill, Trinity College, Dublin / IUA, Ireland.

Self-Organized Routing in Mobile Ad Hoc Networks using SAMPLE. Jim Dowling and Stefan Weber, Trinity College Dublin / IUA, Ireland

Bibliography

Mr. Couture received a B.Sc. degree in Physics and a M.Sc. in Physical Oceanography at the Université du Québec à Rimouski, Qc, Canada. After 8 years of M&S work at Fisheries and Ocean Canada, he completed a M.Sc. in Electrical Engineering at Laval University, Qc, Canada. In 2002, he joined Defence R&D Canada - Valcartier as a Defence Scientist in the Systems Engineering and Architecture (SEA) Group, which is part of the System of Systems (SoS) Section. His research interests are oriented toward the study, design and engineering of military complex systems through the lens of the Complexity Theory.

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